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Guidelines for Preparation of a Cumulative Hydrologic Impact Assessment (CHIA)



**UNITED STATES DEPARTMENT OF THE INTERIOR
Office of Surface Mining Reclamation and Enforcement**

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PREFACE

This volume is one of three that address the requirements of Public Law 95-87 (the Act) and its promulgated regulations related to the protection of the hydrologic balance on and adjacent to surface coal mines. This volume contains Guidelines for Preparation of a Cumulative Hydrologic Impact Assessment (CHIA). Another volume contains Guidelines for the Preparation of a Probable Hydrologic Consequences Determination (PHC). These guidance documents suggest processes and illustrations that applicants and regulatory authorities may use to prepare the required PHC and CHIA. A third volume contains appendices with supporting information for the PHC and CHIA volumes. In addition to the appendix volume, the PHC and CHIA volumes each include appendices specific to the respective document.

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INTRODUCTION

PURPOSE AND SCOPE

The Surface Mining Control and Reclamation Act of 1977, 30 U.S.C. 1201 et seq. (1982) (SMCRA) requires the regulatory authority, before issuing a permit to conduct surface coal mining and reclamation operations, to make an assessment of the probable cumulative impacts of all anticipated mining in the area to assure that the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area. The Office of Surface Mining (OSM) has termed this assessment a "cumulative hydrologic impact assessment" (CHIA). Although SMCRA is very specific that such an assessment is a necessary part of the permitting process, it provides little in the way of guidance as to how these assessments are to be made. The development of this manual provides this guidance to regulatory authorities in the form of a procedure for making technically sound and legally defensible CHIA's.

This guidance document suggests a thought process which will lead the regulatory authority to recognize and address the critical issues of each assessment. More specifically, this document (1) outlines the statutory basis for developing CHIA's and describes the regulatory requirements for CHIA's, (2) provides a process for the development of an acceptable CHIA, and (3) suggests data sources and proven analytical procedures that may be used in the assessment. These suggestions and procedures should be considered guidelines and not standards. The regulatory authority is not required to use this material. This is an advisory document and should not be construed as being regulatory in any way. There are no limits or conditions specified except those contained in the Act itself and in the promulgated Federal regulations and approved State programs.

The CHIA is an assessment which distinct and separate from the determination of probable hydrologic consequences (PHC), although elements of the PHC can be used to support and develop the CHIA. The CHIA is the responsibility of the regulatory authority, whereas the applicant must provide the PHC determination with the permit application. The PHC determination addresses hydrologic conditions on the permit and adjacent areas; the CHIA considers impacts over the entire cumulative impact area (CIA). This guidance document primarily addresses the CHIA process but may refer to information presented in the PHC determinations of the individual operations. It is assumed that prior to starting the CHIA process, the regulatory authority will have reviewed the hydrologic content of the permit application and will have made a determination that the hydrologic information, the analyses, and the PHC statement in the application provide a complete and adequate evaluation of the hydrologic systems that will be affected by the proposed operation and clearly indicate the magnitude of those effects. If such a determination shows these items to be inadequate or if such a determination has not been made, the CHIA process should not be initiated until these items are provided.

This document is directed primarily to the regulatory authorities, who have the responsibility of completing a CHIA for each permit application. However, coal mine operators and interested members of the public may also find it useful for preparing and understanding permit applications. If each party involved in the permitting process understands what is required of the others, conflicts should

occur less frequently and be more easily resolved. It is intended that this document provide a common understanding of the CHIA process for all interested parties.

Because this document is intended for nationwide use, the process presented is intentionally nonspecific. It gives the regulatory authorities flexibility to administer the process within regulatory requirements and standards of the individual States. It emphasizes the general elements that should be considered in conducting a CHIA but allows the regulatory authority to choose the specific approaches and methods that will be most appropriate to a given State, region, or cumulative impact area. Therefore, the prudent regulatory authority will develop State-specific CHIA guidelines, using the process presented here as a framework. Such action would allow the regulatory authority to standardize parts of the process, establish appropriate exceptions to the process, and, in general, streamline the whole CHIA process, thus minimizing the total effort required for a given CHIA analysis.

DEFINITIONS

The following definitions will facilitate the understanding of this document. They are provided solely to aid the reader in understanding this guidance document and are not to be construed in any way as official OSM definitions. Other definitions may be found in OSM's Permanent Regulatory Program, 30 CFR 701.5 (appendix A.1).

Baseline hydrologic information.--Information which describes the physical and chemical characteristics of a hydrologic system and the hydrologic balance of an area prior to the imposition of a specific stress, such as a mining operation.

Hydrologically isolated operation.--A surface mining operation where hydrologic impacts are negligible or are dissipated before reaching points in the system where they are additive to hydrologic impacts of other surface mining operations.

Hydrologic concern.--An issue or potential issue relating to some element or aspect of the hydrologic system which may be adversely affected by surface mining activities. Each concern can be described using specific hydrologic parameters and changes in those parameters. Cumulative impact assessments can be focused initially upon hydrologic concerns identified through analysis of baseline information, historical data, etc.

Hydrologic impact.--Any measurable change in hydrologic parameters or conditions associated with a particular hydrologic system caused by surface and underground coal mining activities.

Hydrologic model.--An equation, set of algorithms, or written qualitative description of a phase of the hydrologic cycle. Most often, an equation that results from the use of correlation-regression analysis that relates a hydrologic parameter to physiographic and climatic factors. Also, a computer program that predicts hydrologic parameters as time-series,

such as streamflow or soil moisture, given meteorologic time-series input. For cumulative impacts of surface mining, the applicable phase of the hydrologic cycle is from precipitation on the land surface or snowmelt to the discharge point at a downstream location or flow in an aquifer.

Hydrologic parameter.--A particular physical or chemical quantity, property, factor, or characteristic used to describe hydrologic conditions.

Material damage to the hydrologic balance means, with respect to CHIA, the changes to the hydrologic balance caused by surface mining and reclamation operations to the extent that these changes would significantly affect present and potential uses as designated by the regulatory authority.

Water availability means that, along with there being a sufficient volume, the water is in an accessible location and it is of acceptable quality for the uses designated by the regulatory authority.

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CHAPTER I

STATUTORY AND REGULATORY REQUIREMENTS FOR CUMULATIVE IMPACT ASSESSMENTS

The statutory requirements for CHIA's are found in Sections 507(b) and 510(b) of SMCRA. These sections which delineate the requirements that the regulatory authority and the permit applicants must meet, state, in pertinent part:

Section 507(b) "The permit application shall be submitted in a manner satisfactory to the regulatory authority and shall contain, among other things-- * * * (11) a determination of the probable hydrologic consequences of the mining and reclamation operations, both on and off the mine site, with respect to the hydrologic regime, quantity and quality of water in surface and ground water systems including the dissolved and suspended solids under seasonal flow conditions and the collection of sufficient data for the mine site and surrounding areas so that an assessment can be made by the regulatory authority of the probable cumulative impacts of all anticipated mining in the area upon the hydrology of the area and particularly upon water availability: Provided, however, That this determination shall not be required until such time as hydrologic information on the general area prior to mining is made available from an appropriate Federal or State agency: Provided further, That the permit shall not be approved until such information is available and is incorporated into the application" (emphasis in original).

Sections 510(b) "No permit or revision application shall be approved unless the application affirmatively demonstrates and the regulatory authority finds in writing on the basis of the information set forth in the application or from information otherwise available which will be documented in the approval, and made available to the applicant, that * * * (3) the assessment of the probable cumulative impact of all anticipated mining in the area on the hydrologic balance specified in Section 507(b) has been made by the regulatory authority and the proposed operation thereof has been designed to prevent material damage to the hydrologic balance outside the permit area;"

The requirements of Sections 507(b)(11) and 510(b)(3) of the Act have been implemented by the Permanent Regulatory Program at 30 CFR 701.5, 780.21, and 784.14. Section 701.5 defines "cumulative impact area," the name given the area referred to in Section 507(b)(11) as that area which must be included in the assessment of probable cumulative impacts. This definition of the CIA addresses the physical extent of the area and the meaning of the term "all anticipated mining" as used in Section 510(b)(3). According to the preamble, anticipated mining is meant to include "all operations which have a reasonable expectation of receiving regulatory approval to mine and for which there is sufficient mine development information available to allow adequate analyses" (48 Federal Register 43957, September 26, 1983).

Sections 780.21(g) and 784.14(f) of the regulations speak specifically to the scope of the CHIA. Section 780.21 addresses surface mining and 784.14 concerns underground mining. These sections both read as follows:

Cumulative hydrologic impact assessment.

- (1) The regulatory authority shall provide an assessment of the probable cumulative hydrologic impacts (CHIA) of the proposed operation and all anticipated mining upon surface- and ground-water systems in the cumulative impact area. The CHIA shall be sufficient to determine, for purposes of permit approval, whether the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area. The regulatory authority may allow the applicant to submit data and analyses relevant to the CHIA with the permit application.
- (2) An application for a permit revision shall be reviewed by the regulatory authority to determine whether a new or an updated CHIA shall be required.

Sections 780.21(c) and 784.14(c) discuss the responsibilities of the regulatory authority and the applicant for the collection of hydrologic data needed for the CHIA. These sections provide:

Baseline cumulative impact area information.

- (1) Hydrologic and geologic information for the cumulative impact area necessary to assess the probable cumulative hydrologic impacts of the proposed operation and all anticipated mining on surface- and ground-water systems, as required by Paragraph 780.21(g) or 784.14(f), shall be provided to the regulatory authority if available from appropriate Federal or State agencies.
- (2) If the information is not available from such agencies, then the applicant may gather and submit this information to the regulatory authority as part of the permit application.
- (3) The permit shall not be approved until the necessary hydrologic and geologic information is available to the regulatory authority.

CHAPTER II

OVERVIEW OF THE CHIA PROCESS

This chapter presents an overview of the CHIA development process, along with the philosophy on which it is based, so that the user can immediately understand its full scope. In addition, brief statements of the functions of each of the process elements are presented. Detailed discussion of the various process elements is presented in later chapters.

PHILOSOPHY OF CHIA

With proper enforcement of surface mining regulations, the hydrologic impacts of individual mining operations will be minimized, though not eliminated entirely. These remaining or residual impacts, however small and individually insignificant, may, with the development of additional mines, accumulate to magnitudes that are significant and potentially damaging to the hydrologic balance. The cumulative hydrologic impact assessment, thus, is necessary to assure that such aggregate impacts will not be overlooked in the routine processing of individual permit applications. In effect, the CHIA is a safety net provision in the Act, and its overall objective is to require routine consideration of the aggregate impacts caused by the disruption of large areas (more than one individual permit area) due to surface mining operations.

The CHIA is a means of keeping the big picture of hydrologic impacts before the regulatory authority at all times, so that if the accumulated impacts reach potentially damaging magnitudes, they can be dealt with in a timely manner. Depending on the hydrologic setting, the potential for damage to the hydrologic system, and the evaluation of the significance of that damage through the application of material damage criteria established by the regulatory authority, the probable cumulative hydrologic impact assessment could result in the denial or delay of a mining permit. The regulatory authority may use the CHIA as a land use planning tool to balance current coal development in a region against probable future development. However, such use is not required (48 Federal Register 43973, September 26, 1983).

Because, through the CHIA process, the regulatory authority is continually reminded of the reality of cumulative impacts, it should not be necessary to completely analyze every facet of the hydrologic system. The process presented in this guidance document is based on the premise that the scope of the analysis can be reduced to those facets of the hydrologic system which are likely to affect the designated uses of water available from that system. At the start of an assessment, its scope should cover all possibilities. Thus, the scope of a CHIA should initially include a complete analysis of the ground- and surface-water systems in the CIA, from the standpoint of water quantity and quality. This initial scope can then be systematically and logically reduced to those concerns considered significant to maintaining the hydrologic balance of the area. The scope reduction procedures, which must be developed by the regulatory authority, are envisioned to often be qualitative in nature.

The procedures presented here are based on the understanding that hydrologic impact assessment is not a precise process. Because of the many uncertainties associated with hydrologic estimation, the predictions made under the process proposed herein, or under any similar process, must be considered as **probable** in nature rather than exact. Therefore, the regulatory authority must have the option of using professional judgment to make the final material damage determination. This should not detract from the significance of the process if the determination is based on the facts produced by a comprehensive analysis. Likewise, use of qualitative methods and techniques for the analysis is an acceptable option if the regulatory authority can show them to be adequate for the specific site situation.

OVERVIEW

A CHIA is a permit-specific assessment required by SMCRA and must be an integral part of the permit decision package. The CHIA should be included in the Technical Environmental Analysis (TEA) section of the decision package.

CHIA development is a **process** which consists of a logically and professionally documented evaluation of a defined set of elements. It basically involves the analysis of critical aspects of the hydrologic system within the cumulative impact area. Emphasis of the analysis is on predicting the type and magnitude of impacts to the hydrologic system attributable to the proposed operation in conjunction with existing operations and anticipated mining. Thus, during the CHIA process, the regulatory authority should (1) define the area to be studied, (2) describe the hydrologic system and determine baseline hydrologic resource values, (3) identify hydrologic resources likely to be affected, (4) develop standards for evaluating the impacts, (5) estimate the impacts of mining on the hydrologic resources, and (6) make a material damage determination and prepare a statement of findings. The regulatory authority should address these elements in a logical sequence based on good hydrologic practice.

Within the constraints of good hydrologic practice and those imposed by statutory and regulatory requirements, the regulatory authority has wide latitude to determine the exact manner in which individual elements will be evaluated. Thus, an assessment based on "professional judgment," or a rigorous analytical assessment may be used, as the situation requires. Also, some of the procedures and hydrologic concerns presented and discussed in this guidance document may not apply to every CHIA. They are offered as examples, and their use is in no way mandatory. The specific concerns, procedures, methods, and data needs may vary with each impact area, and the regulatory authority has complete latitude to use those that best apply to the particular conditions of each site. However, justification for the specific assumptions and decisions made by the professionals conducting the assessment must be included in the findings statement for use in the various review processes (including public review and the program oversight review). The justification of actions and methods should be considered an extremely important aspect of the CHIA process.

Each CHIA should be considered unique to a specific minesite or permit area. However, a totally new analysis is not necessary for each CHIA. It is acceptable to use portions of a previously prepared CHIA for the same area, provided that these portions do, in fact, describe the situation of the newly proposed operation. For

example, if the proposed permit area was included as a leasehold in a previous CHIA, then that previous CIA delineation may be an appropriate CIA for the CHIA of the newly proposed permit area. In addition, documentation of the procedures used to delineate this CIA should be transferable to the CHIA of the proposed mine with only minor modifications. Likewise, once material damage standards have been established for a specific area, they would be applicable, with little modification, to all future CHIA's in that area. Thus, even though a CHIA should be considered unique to each specific permit application, the actual assessment can draw heavily on the previously prepared CHIA's.

Figure II-1 illustrates the basic CHIA process that may be used by the regulatory authority. The letters in the element boxes are for reference only and do not imply a required process order. The process could be depicted in other, equally acceptable, sequences. The important factor is that the process considers the recommended elements in a logical and workable sequence.

The process illustrated in figure II-1 shows the interrelation of the elements to each other and to the process as a whole. The parallel arrangement of Elements A, B, and C is meant to suggest that these elements are highly interrelated and that their evaluation should take place concurrently and interactively. As a group, these three elements are evaluated first in the process because they provide an information base which forms the basis for selecting techniques and methodologies needed for impact prediction and material damage assessment. The sequential arrangement of Elements D through F indicates that completion of these elements is dependent on the prior evaluation of certain other elements. This should not be construed to mean that one element must be totally completed before the next is started. The feedback arrow suggests that the CIA delineation may need modification after the areal extent of the impacts has been evaluated.

Process Elements

Element A.--Element A addresses the delineation by the regulatory authority of the area for which the CHIA is being prepared. OSM refers to this area as the cumulative impact area (CIA) and defines it in the regulations (30 CFR 701.5) in terms of both a physical area and the type of operations located within the area that must be considered.

The proposed delineation process begins at a point downstream from the most downstream operation in the same river basin where the proposed operation is located. By procedures developed by the regulatory authority, operations spatially and hydrologically distant from the proposed operation are systematically tested to determine the significance of their impacts with respect to the proposed operation. In this way, the CIA is limited to operations whose hydrologic impacts are relevant to the CHIA being developed. The process may be iterative, with some evaluation of the impacts needed before the limits of the CIA can be finally delineated; thus, the feedback loop from Element E to Element A in figure II-1.

Element B.--Element B involves identification by the regulatory authority of hydrologic concerns specific to the CIA. This is a qualitative identification of the aspects of the hydrologic system most likely to be adversely affected by mining activity. By identifying hydrologic concerns peculiar to the CIA, the CHIA process

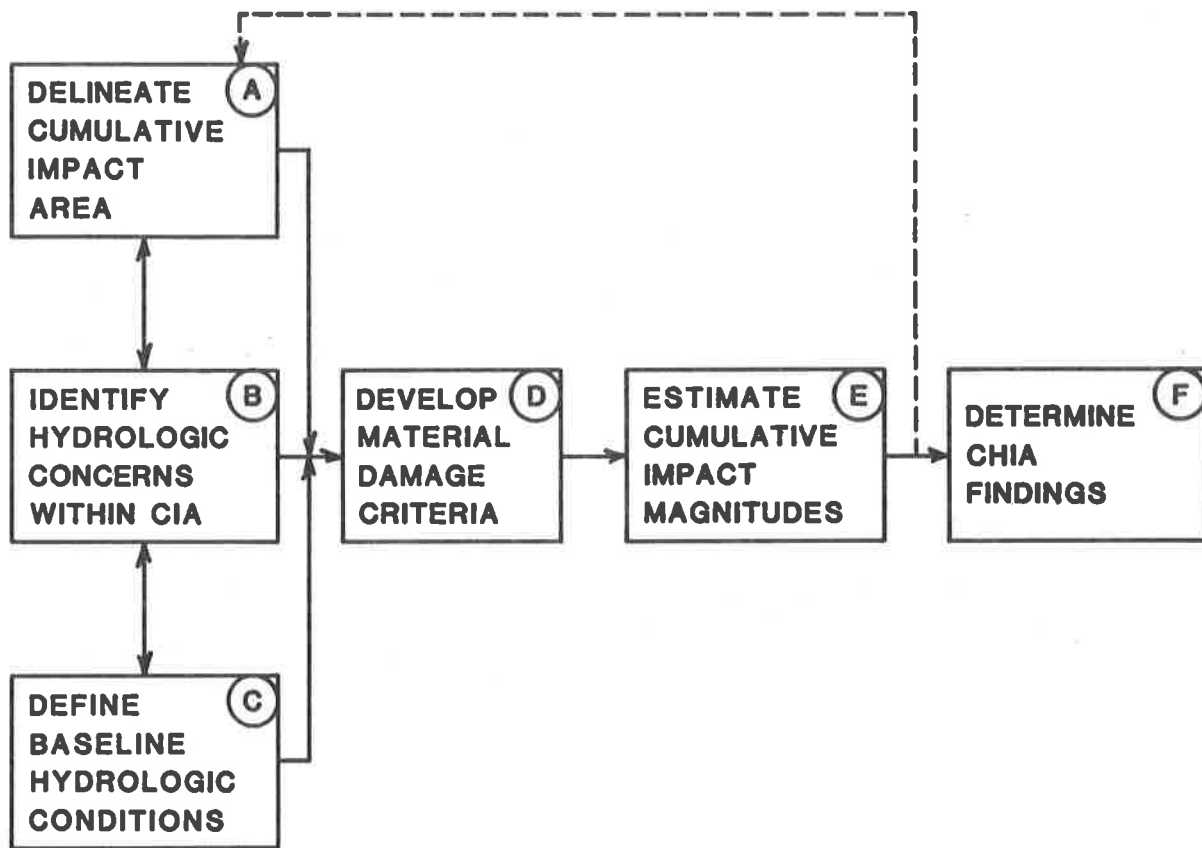


Figure II-1.--Flow diagram of basic CHIA process.

can be focused on these critical segments of the hydrologic system. The concerns can be identified from PHC data, as well as from other baseline data, historical data, or any source that raises valid questions about some aspect of the hydrology of the CIA. The specific parameters to be used to measure and evaluate the concerns, and the sites at which the concerns will be evaluated should also be identified. These parameters will be referred to as "indicator parameters" in the remainder of the guidance document. For example, a common concern associated with mining in the Western United States is increased salt concentration in the postmining ground-water supplies.

Element C.--Element C provides for the determination of baseline hydrologic conditions of the CIA. This determination should result in a description of the hydrologic system and how it functions. It should also provide the normal values of the indicator parameters at the beginning of mining. In effect, baseline conditions are indicators of the state of the hydrologic balance at the time of the analysis, and they provide reference points for evaluating the significance of future impacts (predicted values of indicator parameters) of mining.

Element D.--Under Element D, the regulatory authority establishes for the indicator parameters the threshold values beyond which material damage is likely to occur. It is here that the regulatory authority establishes what constitutes material damage for the CIA. Existing State and Federal water-quality standards should be used where applicable. Where standards are not already available, the regulatory authority will have to develop threshold values. These values normally will be in the form of maxima or minima, but, in some cases, rate-of-change limits (incremental limits) may be necessary. When, with increasing numbers of mines in the CIA, impact levels approach material damage threshold limits, the regulatory authority may wish to establish secondary limits (parameter value less than the material damage thresholds) to indicate when more rigorous and precise analysis procedures should be used.

Element E.--Element E involves estimating values that the indicator parameters are expected to attain as a result of coal mining. First, an analytical approach is adopted. If the combinational approach is used, specific analysis techniques should not be necessary because adequate impact assessments should already exist in the PHC's of the individual anticipated operations. In this case, the regulatory authority needs only to develop procedures by which the results of the individual PHC's can be rationally combined. If PHC's are not available for some of the "anticipated mining" operations, the regulatory authority must first develop PHC's or make equivalent analyses in order to use the combinational approach.

If the independent analysis approach is used, then specific techniques are necessary. Technique selection depends on many factors, but a primary consideration should be that the technique adequately account for the dominant physical conditions that characterize the subject hydrologic system. The selected techniques are applied to the total CIA using data assembled at Element C. The approach and techniques selected are extremely important to the outcome of the CHIA process and should be given careful consideration.

Element F.--The regulatory authority's final task in the CHIA process (Element F) is to determine whether the hydrologic assessment of the CIA (Elements A through E) indicates that the addition of the impacts of the proposed operation to those of the other anticipated mining may cause material damage to the hydrologic balance outside the permit area and to write a statement of these findings with all supporting evidence and rationale. The determination is the main objective of the whole CHIA process. The supporting evidence and rationale validate the determination.

The determination may be based on quantitative comparisons and/or on qualitative evaluations. Quantitative comparisons should be made whenever possible, but they need not be the sole basis for the determination. The regulatory authority has the flexibility of using qualitative factors along with quantitative comparisons to make final material damage determinations. Regardless of whether the determination is qualitative or quantitative, the rationale for the decisions must always be clearly stated.

The written statement of findings with supporting evidence and rationale should describe the actions taken to complete each of the process elements, with emphasis on justification for these specific actions or decisions. As a matter of expedience, this writing is suggested to be considered a part of each of the other elements, with the appropriate sections being completed as these elements are processed. In this way, the bulk of the writing will be completed when the analysis is completed. Then, in Element F, the statement would require only finalization. A suggested form and content for this document is given in Appendix A.

CHAPTER III

CHIA CONCEPTS

The CHIA is a novel concept for environmental protection, and all its possibilities should be explored in the process of developing working procedures for its implementation. An important first step toward compliance should be for the regulatory authority to develop a clear understanding of the language and the new terms used in the Act and regulations. This guidance document addresses the terminology in several places. The "Introduction" section defines terms not previously defined in 30 CFR 701.5. This chapter, Chapter III, expands upon, and explores in a broad and conceptual manner, the definitions of the terms "material damage to the hydrologic balance" and "cumulative impact area." These terms are further treated in Chapter IV, which suggests practical, working procedures for implementing the requirements conveyed by the terms. If the reader keeps in mind the differences in the various treatments of this terminology, the appearance of repetition should be minimized.

CONCEPT OF CUMULATIVE HYDROLOGIC IMPACTS AND CUMULATIVE IMPACT AREA

The focus of the CHIA assessments should be on the changes (type and magnitude) and conditions that are the direct result of large areas being mined by more than one operation and the possibility that these changes will result in material damage outside the permit area. In the following discussion of impacts and impact areas, the terms "mine" and "mining" refer to mining operations that are included in the definition of "anticipated mining."

To some users of this guidance document, the term "impact" may connote a severe or adverse condition. As used in this document, however, an impact is "any measurable change * * *." Therefore, a distinction is made between the occurrence of an impact and the severity of the impact. In general usage here, the term "impact" will refer only to the specific changes that are expected to occur and to the geographical area where they are expected to occur. It does not imply that the expected changes (impacts) will be damaging to the hydrologic balance; only that they may occur. Determination of the potential seriousness of the impacts is considered a separate and distinct problem in the CHIA process.

Clarification of the term "impact area" is also needed. A "hydrologic impact" is defined (see "Definitions") as "any measurable change in hydrologic parameters associated with a particular hydrologic system caused by surface and underground coal mining activities." It follows, then, that the impact area of an individual mine is the geographical area over which the mining activities cause measurable changes to the hydrologic system. The changes are expressed in terms of parameters representative of the hydrologic system. The mine's "true" impact area, then, is a composite of the subareas over which each hydrologic parameter is affected.

The only way to delineate the "true" impact area of a mine is by monitoring the representative parameters at numerous sites over the total time period during which the impacts occur (from before mining until after hydrologic equilibrium is restored after mining). Of course, the impact area would not be known until after the mining and reclamation were completed and, therefore, would not be useful for preparing CHIA's. Therefore, for PHC and CHIA purposes, the size, shape, and position of the impact areas must be estimated. The following discussion of true cumulative hydrologic impacts and cumulative impact area is offered to provide a basis for estimating the practical, "working" impact area.

"Cumulative hydrologic impacts" are the aggregate effects on hydrologic parameter values at a particular location in the hydrologic system, caused by existing and anticipated mining activities. The term is best explained by illustration. Consider the group of mines and leases depicted in figure III-1. Suppose that, at any downstream point, W, in the surface flow system, surface-water quantity and quality parameters could be monitored from a time prior to mining until the system regains equilibrium after the mining. This monitoring would provide a measure of the cumulative effects of the mining on the surface hydrology at point W. Plot A in figure III-2 shows the variation in total salt load over the monitoring period. The difference between the salt load value at any time, t, and the premining value would represent the accumulated change in salt load at time t caused by the mining. This assumes that there are no other types of development activity in the area to affect the system. Since several mines would have contributed dissolved salts into the flow system, this plot depicts the "cumulative" effect of these mines on salt load at point W. Similar measurements and plots at sites X and Y would show the cumulative impacts at those points.

From the preceding illustration, it should be apparent that the true cumulative hydrologic impacts are the net accumulated changes caused by the anticipated mining operations as integrated (combined) by the hydrologic system. The true cumulative impacts are not simple summations of the impacts from a group of individual mines selected according to rigid rules or on some arbitrary basis. Rather, they are the result of stresses on the system and their actual magnitudes can be found only by measurement. The impact values will vary, depending on where in the system and at what point in time they are measured. For CHIA purposes, the maximum expected changes are the relevant values.

As figure III-1 implies, the true impact accumulation area from several mines is not necessarily restricted to the immediate vicinity of the mines. In general, the impacts of concern will affect the quality or quantity of water in the hydrologic system, and most impacts will be transported by, or will in some way be related to, water flow through the system. Therefore, the impacts of a mine can be expected to move mainly downgradient, and the accumulation of impacts of two or more mining operations may occur at locations quite remote from their respective permit areas, or at a time far in the future. Therefore, when impacts of several mines feed into the same flow system as does the proposed mine, and irrespective of the relative locations of the mines within that system, there is theoretically a potential for accumulation of impacts.

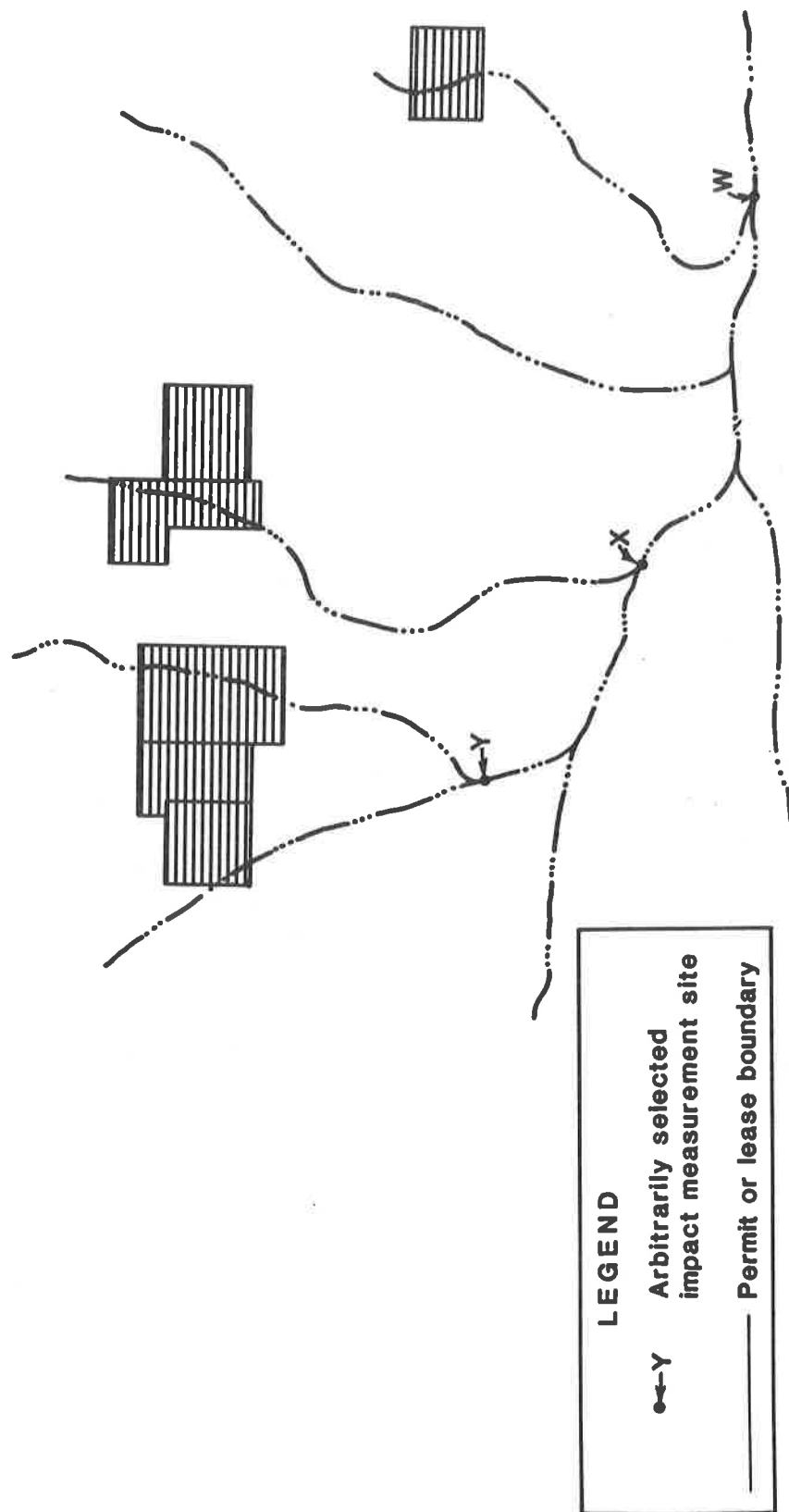


Figure III-1.--Hypothetical sites for measurement of "true" cumulative hydrologic impacts.

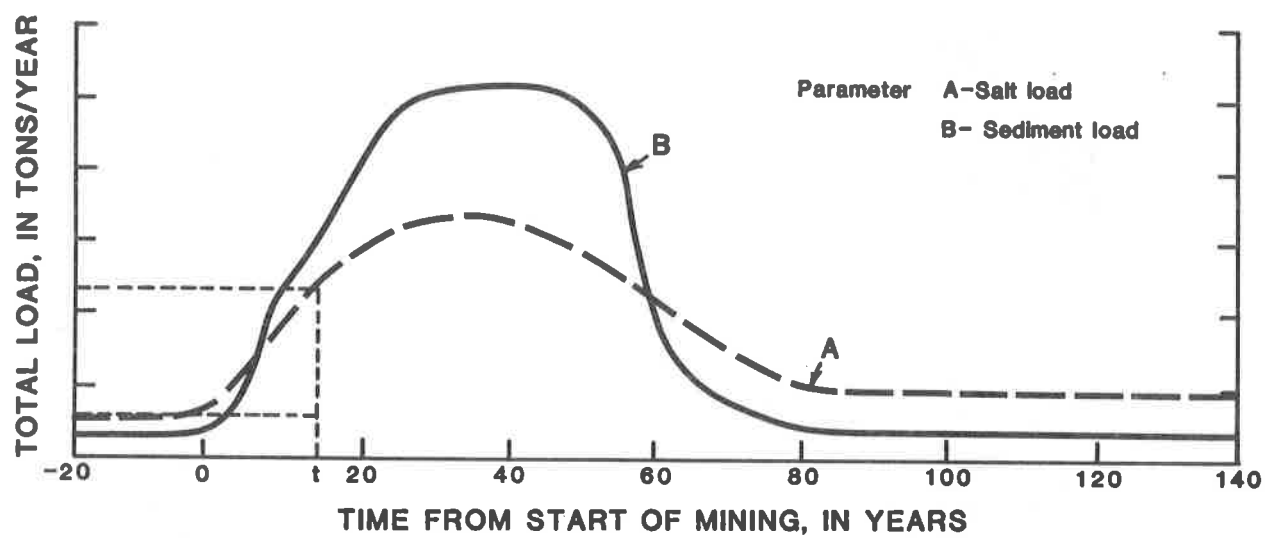


Figure III-2.--Plots of hypothetical cumulative hydrologic impacts measured at point W of figure III-1.

Following this line of reasoning, all mines within the same river system or ground-water flow system have the potential for impact accumulation with the proposed mine, and it could be argued that the CIA must extend to a point downgradient from the most downgradient mine in the river system. However, it is unlikely that Congress intended a CIA to routinely include whole river systems, as might be required if the preceding rationale were strictly followed. Therefore, the downstream extent of a CIA that is environmentally comprehensive and also satisfies the intent of the Act probably lies somewhere between the downstream boundaries of the proposed permit area and the farthest downstream mine in the river basin. The regulatory authority should develop a rational procedure for identifying this point. Preferably, the procedure would be based on hydrologic and mathematical theory and on professional judgment, rather than on professional judgment alone.

MATERIAL DAMAGE TO THE HYDROLOGIC BALANCE

The term "material damage to the hydrologic balance" may have various interpretations. The following discussion presents a conceptual interpretation of this term. The Permanent Program Regulations do not define "material damage" but do define "hydrologic balance" as "the relationship between the * * * water inflow to, water outflow from, and water storage in a hydrologic unit, such as a drainage basin, aquifer, soil zone, lake, or reservoir" (30 CFR 701.5). According to this definition, the hydrologic balance of a particular unit of the hydrologic system is the relationship of the inputs and outputs of water, and the full range of materials it may contain, to the unit. The specific relationship depends on the physical characteristics of the hydrologic unit and reflects gains and losses of output imposed by those characteristics. The balance of a hydrologic system, such as that within the CIA, can be thought of as the integrated relationship between all water inputs to and outputs from one or more hydrologic units that make up the system. These relationships can be quantified and defined by measuring the outputs and the corresponding inputs. One intended use of baseline hydrologic information is to define the existing preoperation relationships of the hydrologic system. Subsequent changes in system outflow may be considered as a measure of changes in the hydrologic balance, if the inflow is assumed to remain unchanged over the time period evaluated by the CHIA.

The concept that changes in the hydrologic balance are analogous to changes in the outputs of the system is illustrated graphically in figure III-3. Curve A represents a premining state of hydrologic balance between precipitation and runoff from a permit area. An example from the curve shows that 5 units of precipitation will produce approximately 25 units of runoff. When the area is mined, the consequent alteration of physical characteristics will result in some change in the relationship between precipitation and runoff. Curve B represents an estimate of this postmining state of the hydrologic balance. It shows that the area now produces only 15 units of runoff from 5 units of precipitation. The difference in runoff between curves A and B represents the predicted change to the hydrologic balance at a given input level as a result of mining. Quantitatively, the difference represents the change in outputs (runoff, in this case) caused by the altered physical state of the hydrologic system. This concept can be extended to all relationships used in the impact analysis. In developing an actual CHIA, quality as

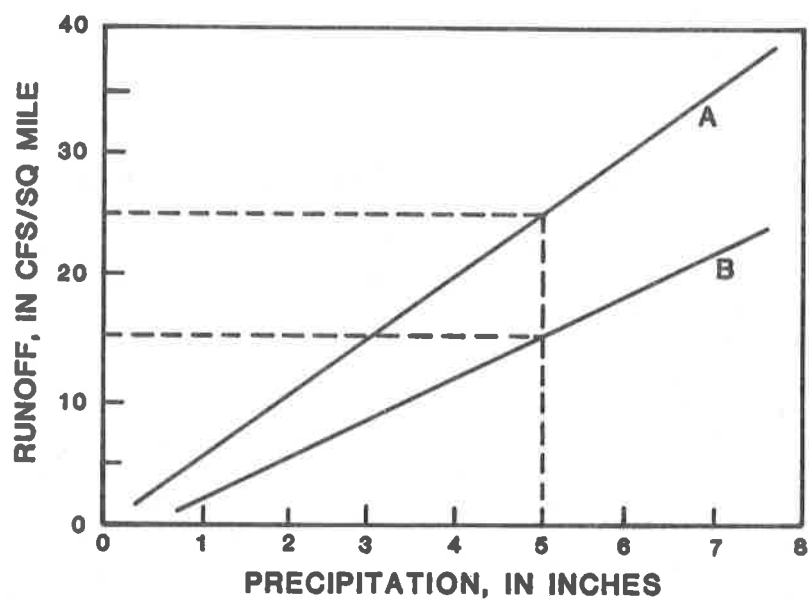


Figure III-3.--Hydrologic balance between runoff and precipitation for (A) premining conditions and (B) postmining conditions.

well as quantity relationships must be considered. The outputs discussed in the foregoing should be recognized as the parameters identified in Element B as the indices of the hydrologic concerns within the CIA.

Material damage to the hydrologic balance may be characterized by changes to the quality or quantity of surface water or ground water as measured by changes in particular hydrologic parameters or conditions. In terms of the foregoing discussion of hydrologic balance, this means that material damage occurs when postmining outputs exceed defined limits, or when the change in output which occurs in going from the premining relationship (e.g., the state of hydrologic balance) to the postmining relationship exceeds some prescribed amount. The establishment of allowable limits and of allowable increments of change for each parameter identified in Element B is the task to be accomplished in Element D. These limits are referred to in this guidance document as the Material Damage Criteria.

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CHAPTER IV

ELEMENTS OF THE CHIA PROCESS

This chapter describes, in detail, the various elements that constitute the CHIA process.

ELEMENT A. DELINEATION OF CUMULATIVE IMPACT AREA

Element A deals with identification by the regulatory authority of the geographical area that the CHIA is to evaluate. The end product of this element is a delineation of the area within which cumulative hydrologic impacts of the proposed mining are expected to occur. Determination of the cumulative impact area should focus on the identification of the total area that contributes to the magnitude of hydrologic impacts outside the permit areas. Inherent in this identification process is the need to define the specific hydrologic system and to understand how it functions. Such understanding will facilitate CIA delineation, as well as the whole CHIA process, and will result in more rational and complete assessments.

OSM refers to the area which the regulatory authority must evaluate for the required CHIA as the "cumulative impact area" (CIA). The definition of CIA (30 CFR 701.5) provides the regulatory requirements for the delineation of a CIA. These requirements are very specific about the type of operation that must be evaluated but leave unclear the extent of the geographical area required for CHIA consideration. However, the parts are somewhat interdependent in that the CIA must include the impact areas of all "anticipated mining" operations, but "anticipated mining" includes only those operations that lie within the CIA. The preamble to the final rules (48 Federal Register 43956-43959, September 26, 1983) devotes considerable space to discussion of this definition and to comments received from the public relative to the definition. The reader is referred to this material in addition to the following discussion.

All Anticipated Mining Operations

The discussion of cumulative impact area concepts (Chapter III) centers on the geographical area alone. The other part of the CIA delineation process, discussed below, involves identification of the specific operations whose impacts must be included. The definition of CIA specifies the types of operations, which, at a minimum, must be included as "anticipated mining." In addition, "anticipated mining" also includes a time factor; that being, "at a minimum, the entire projected lives through bond releases of:" the above-listed types of operations (30 CFR 701.5, Cumulative Impact Area). This means that the total areas projected to be disturbed by mining and reclamation activities over the entire lives of these operations (not just the 5-year permit areas in effect at the time the CHIA is prepared) must be included in the CIA.

Of the specified types of operations, the proposed operation, existing operations, and operations for which permit applications have been submitted to the regulatory authority are most easily identified. Submitted applications are those which the regulatory authority has in hand, whether or not the application

has been certified as complete. Existing operations are those for which bond has not been released on the total mine plan area. Unpermitted operations, such as those of less than 2 acres for which a permit may not be required, are considered as existing operations and must be included in the assessment (48 Federal Register 43958, September 26, 1983). Completed operations--those for which total bond has been released prior to submittal of application for the proposed operation--need not be considered. It can be assumed that the CHIA baseline data will reflect any remaining impacts of completed operations.

The definition of Federal coal leases that must be included in the CIA needs amplification. By definition, Federal coal leases required to achieve diligent development need to be considered. More specifically, those Federal leases for which sufficient hydrologic, geologic, and mine development information is available to allow for accurate hydrologic impact assessment (such as planned mining and reclamation techniques, processes, schedules, etc.) must be considered. Federal coal leases exempt from diligence requirements and State and private leases may also be included as "all anticipated mining" if the regulatory authority deems it necessary.

All Federal coal leases and logical mining units (LMU's) issued after August 4, 1976, are required to achieve diligent development (Federal Register 33187, July 30, 1982). Federal coal leases issued prior to August 4, 1976, are required to achieve diligent development upon the effective date of the first lease readjustment after August 4, 1976. Any Federal coal lease included in an LMU is subject to the diligent development requirements imposed on the LMU (Federal Register 33187, July 30, 1982).

In addition, the amended Mineral Leasing Act (1920) requires that the lessee submit a resource recovery protection plan (RRPP) within 3 years of the effective date of a Federal coal lease. The RRPP must contain certain mine development information, as specified in 30 CFR 211.10. Leases obtained prior to August 4, 1976, are exempted from such requirements until the effective date of the first lease readjustment occurring after August 4, 1976. For the purpose of defining "all anticipated mining" in the CIA, it is suggested that the information required in the initial submittal of the RRPP for a Federal lease tract be used to satisfy the "sufficient mining development information" requirement in the definition of "anticipated mining." With this condition, only those Federal leases issued after August 4, 1976, and LMU's approved after that date for which RRPP's have been submitted and approved would have to be included in the cumulative impact area. Leases and LMU's effective before August 4, 1976, would not have to be considered as anticipated mining until they become subject to diligence and RRPP requirements after the first readjustment. Again, the regulatory authority may include, as anticipated mining, other operations, leases, and lands it deems appropriate.

In general, "anticipated mining" includes, as a minimum, all operations which have a reasonable expectation of receiving regulatory authority approval to mine and for which there is sufficient mining development information available to allow an adequate analysis (48 Federal Register 43957, September 26, 1983).

Delineation of a Working CIA

The need for a defined work area within which to conduct the CHIA is obvious. However, because it is impossible to delineate the "true" cumulative impact area before the impacts occur, the CHIA process must depend on an estimated CIA. (See Chapter III for discussion of true and working CIA's.) A CIA that is not excessively large yet accounts for all operations that may produce cumulative hydrologic impacts must be delineated. The delineation procedure that follows will help to specifically define such an area. This defined area is an estimate of the true CIA and will be called the working CIA.

An outline of the procedure is presented on pages IV-6 and IV-7. It consists of two phases and begins with consideration of a broad-scale CIA, which is subsequently reduced to a practical "working" CIA. Phase I provides for reduction of the broad-scale CIA to an intermediate area within which the working CIA can be delineated. Phase II accomplishes actual delineation of the working CIA. Once Phase I is applied to a region, the results should be generally applicable with little modification to subsequent CHIA's for the same vicinity. Phase II is the heart of the delineation procedure, will require the most effort, and should be applied to each individual CHIA separately. Both phases are necessary for a comprehensive delineation of the CIA.

To this point the CIA has been and will continue to be discussed as a single area unless otherwise stated. However, the surface- and ground-water systems are usually analyzed separately, and the impacted area of the ground-water system may very likely be entirely different in size and shape from the surface-water impacted area. Therefore, it may be advantageous for the regulatory authority to develop separate procedures for delineating surface- and ground-water CIA's. Such procedures must recognize and account for the interrelationships between the surface- and ground-water systems. The composite of these surface- and ground-water CIA's constitutes the working CIA.

Discussion of CIA Delineation Procedure

Phase I

The key to Phase I is development by the regulatory authority of specific criteria with which to test the impact significance of operations or groups of operations that are spatially and hydrologically distant from the proposed operation. These criteria can also serve to identify proposed operations that are "hydrologically isolated"; the CHIA's of such operations can be limited to the impacts of the proposed operation. The criteria should allow a quick evaluation of distant operations, but they should also be indicative of situations that may prove significant under more rigorous analysis. The criteria must not allow exclusion of operations in the immediate vicinity of the proposed operation whose impacts are likely to interact with those of the proposed operation. Once criteria have been developed and applied in a given region, the results should be applicable to subsequent CHIA's with little additional effort.

Possible approaches for developing such criteria follow; others may be equally appropriate. One approach is to compare the accuracy with which impacts can be measured at downstream sites in the surface-water system with the expected magnitudes of the impacts at the mines. By definition, a hydrologic

impact is a "measurable change." Therefore, impact magnitudes that are less than the inherent error of the measurement technique used could be considered to have insignificant accumulation potential with mines even farther downstream. Criteria based on this approach should specify, at a minimum, the parameters to be evaluated, the measurement methods to be used, and the associated ranges of measurement error.

A similar approach would use the dilution effect in the downstream direction as the basis for exclusion. At the point in the flow system where the pollutant concentrations become diluted to a predetermined level, the concentrations could be considered insignificant in a cumulative sense, and operations farther downstream could be excluded. Criteria based on this approach should specify what parameters to use for determining threshold dilution magnitudes and the threshold dilution levels.

Some States have quality standards for water entering from adjoining States. Where they exist, these standards could be the basis for exclusion criteria. It would be pointless to consider additional downstream mines if water in the system already fails to meet such standards. The regulatory authority might also take the position that if the water does meet these standards, then the State's obligations for cumulative impacts with out-of-State mines have been met. A possible drawback to this reasoning is that incentives to minimize cumulative impacts on a mine-by-mine basis are lacking until impacts have become of such magnitude that the standards are in danger of being exceeded.

Once developed, the criteria can be applied to mark the extremes of the working CIA along receiving streams common to two or more mining operations (these will be referred to as common receiving streams or common streams) in the vicinity of the proposed operation. Several limiting points may be necessary where more than one common stream originate in a probable CIA. When appropriate, upstream as well as downstream points should be located. The criteria can be applied to any logically selected point in the stream system; then to other upstream or downstream points, as the results indicate, until the criteria are satisfied; or, using a more systematic procedure, begin just upstream from the most downstream cluster of mines and proceed upstream to other clusters until the criteria are met. The delineated watershed area between the identified points is the first approximation of the working CIA.

Phase II

In Phase II, the area delineated above is refined and redelineated. The **first step** (see pages IV-6 and IV-7 for outline of procedure steps) of this phase is to identify all "anticipated mining" within the area. The types of operations that must be included have been discussed previously (see pages IV-1 and IV-2) and their identification should be routine. Identification of the downstream limit of the surface-water CIA (Step 2) simply involves locating a point downstream from the confluence of a common receiving stream with any tributary channels whose flows are likely to be affected by mining. Any stream that drains any part of a mine plan area or is close enough to a mine area to be affected by ground-water impacts should be included.

The downgradient limits of the ground-water CIA are defined in Step 3. This involves identification of the areas in which the strata and water levels in the

strata will be affected by mining or through which affected ground water may flow to reach a discharge point. Identification of strata likely to be affected by the anticipated mining operations and for which there is significant concern, and identification of aquifer recharge and discharge areas are a function of Element B and details of that process are discussed there.

The information necessary for delineation of ground-water drawdown areas and of areas through which plumes of degraded water may migrate should be available for all the anticipated operations which have submitted mine plans (PHC determination sections). For those operations for which PHC's are not available (qualifying leases), the regulatory authority will have to estimate the extent of these areas if this information is needed. Estimates based on information obtained from the PHC's of nearby operations should be adequate for most CIA delineation purposes.

Identifying those stream reaches in which the stream is losing water to the aquifer or gaining water from the aquifer may be more difficult, but this identification is important to understanding how the hydrologic system functions within the CIA. Such reaches are basically aquifer recharge or aquifer discharge (depletion) areas and therefore serve to transmit impacts from the ground to surface systems or vice versa. The PHC determinations in the individual permit applications should identify such reaches, but the regulatory authority should verify that all stream reaches important to the recharge or depletion of aquifers within the CIA have been identified.

Actual delineation of the working CIA is accomplished in Step 4. The procedure provides for separate delineation of surface- and ground-water CIA's; then, an area that encompasses both these CIA's is delineated as the working CIA.

The surface-water CIA boundary can be delineated by beginning at the downstream limits identified in Step 2.A and tracing along the natural drainage divides, or along the boundary delineated in Phase I, so as to completely encompass the impact areas of the operations identified in Step 1. The maximum upstream extent is the watershed boundary or any upstream limit identified in Phase I. It may be permissible to eliminate portions of this area. For example, if all the mining operations are on one side of a river valley, most of the watershed area on the opposite side of the river probably would not have to be included in the CIA because it is not directly impacted. However, the river valley floor and the floors of any common receiving streams must be included because these areas may be directly impacted, either by surface flows or by ground-water flows through the alluvium. The minimum working CIA should include the total watershed areas of all streams that flow across the mine plan areas of the anticipated mining operations and the proposed operation. It should also include all the area between any of the anticipated operations and the area from the operations to and including the valley floors common to receiving streams. Figure IV-1 depicts a surface CIA delineated by this procedure.

A ground-water CIA should be delineated for each impacted aquifer. The area over which a ground-water aquifer is impacted by mining basically extends from the minesites to the aquifer's discharge points. As with the surface CIA, an aquifer CIA should include all the area between the individual anticipated mining operations, as well as between the operations and the aquifer discharge points. In

addition, areas of projected potentiometric drawdown resulting from pit dewatering and production water withdrawals must be included.

Most aquifers affected by surface mining will somewhere discharge to the surface. At these places, the ground-water impacts become surface-water impacts. These discharge points can often be considered as one boundary of the ground-water CIA. The discharge areas of some regional aquifers may be so far away from the mined area that migration of degraded water to these points will take many years. The CIA boundaries for these aquifers can be taken as the estimated extent of degraded water plumes at a selected point in time after the plumes begin migration from the reclaimed spoils. Rationale for the time period used in these calculations should be discussed in the findings. The boundary of the aquifer CIA should surround the maximum extent of all degraded water plumes and drawdown cones expected to occur in the aquifer, including the areas between individual plumes and cones.

The ground-water CIA is the composite area of the individual aquifer CIA's, and, finally, the working CIA is the composite of the surface- and ground-water CIA's. Figure IV-2 depicts a ground-water CIA delineated by the outlined procedure. The working CIA, composited of the CIA's depicted in figures IV-1 and IV-2, is shown in figure IV-3.

Procedure for Delineating the CIA

(Evaluate interactively with Elements B and C)

Phase I.--Define maximum upstream and downstream extent of CIA.

- Step 1. Develop criteria for excluding operations from the CIA that are spatially remote from the proposed operation but that are within the same major surface drainage system.
- Step 2. Apply criteria to locate maximum extent of working CIA, both upstream and downstream from the proposed operation.
- Step 3. The watershed area between these points is the first approximation of the CIA.

Phase II.--Delineate working CIA within area defined in Phase I.

- Step 1. Identify all anticipated mining operations (i.e., life-of-mine areas of proposed operation, existing operations, operations with submitted applications, and Federal leases with diligence requirements) within the area defined in Phase I.
- Step 2. Identify the downstream limit of the surface-water CIA.
 - A. Identify on a receiving stream common to two or more anticipated mining operations a point downstream from all tributary stream

channels whose flows are likely to be affected by the mining. Consider this point as the downstream limit of the surface-water CIA on that stream. Repeat on other receiving streams, as necessary.

Step 3. Identify the downgradient limit of the ground-water CIA.

- A. Identify all geologic strata likely to be affected by the anticipated mining operations, including aquifers. Also, identify recharge and discharge areas for the aquifers.
- B. Delineate area over which ground-water quantity and quality may be affected by the identified mines.
 - i. Delineate area of ground-water drawdown caused by each operation in each identified aquifer.
 - ii. For each identified aquifer, delineate area that ground-water pollution plume from each operation would pass through in moving from the mine to probable discharge points.
 - iii. Identify probable stream reaches that discharge into or receive discharge from ground-water aquifers affected by the identified mining operations.

Step 4. Delineate working CIA.

- A. Surface-water CIA
 - i. Delineate surface-water CIA boundary along natural drainage boundaries which completely encompass all the impact areas of the operations identified in Step 2.A.
- B. Ground-water CIA
 - i. Delineate ground-water CIA boundary to encompass the maximum extent of pollution plumes and areas of drawdown cones. Include all cones and plumes that affect or discharge to common surface streams or alluvial aquifers, or are contiguous with cone and/or plume of proposed operation.
- C. The composite of the surface- and ground-water CIA's is the working CIA for the proposed operation.

The product of this procedure is a working CIA with which to begin CHIA evaluation.

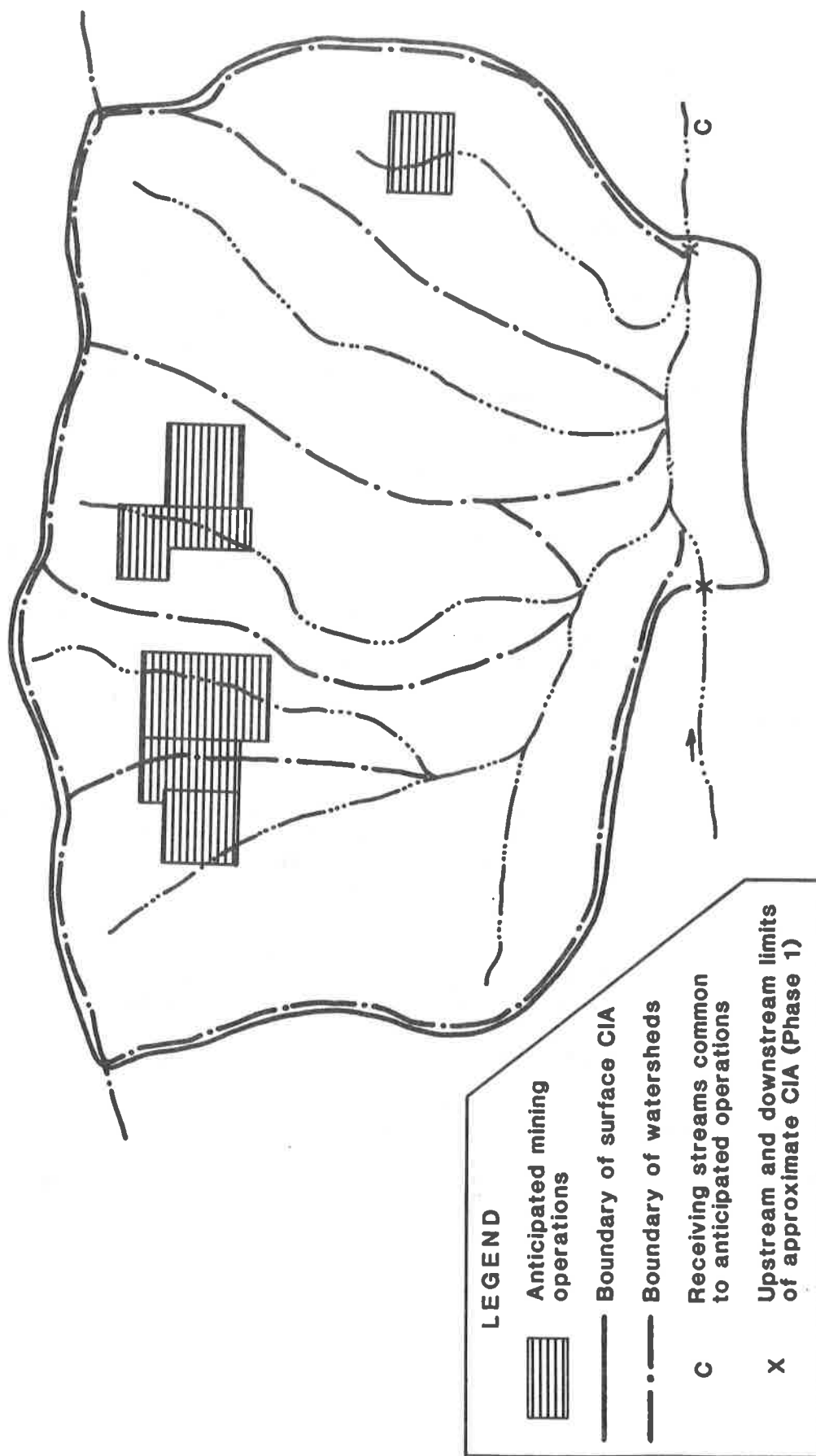


Figure IV-1.--Delineation of surface-water CIA.

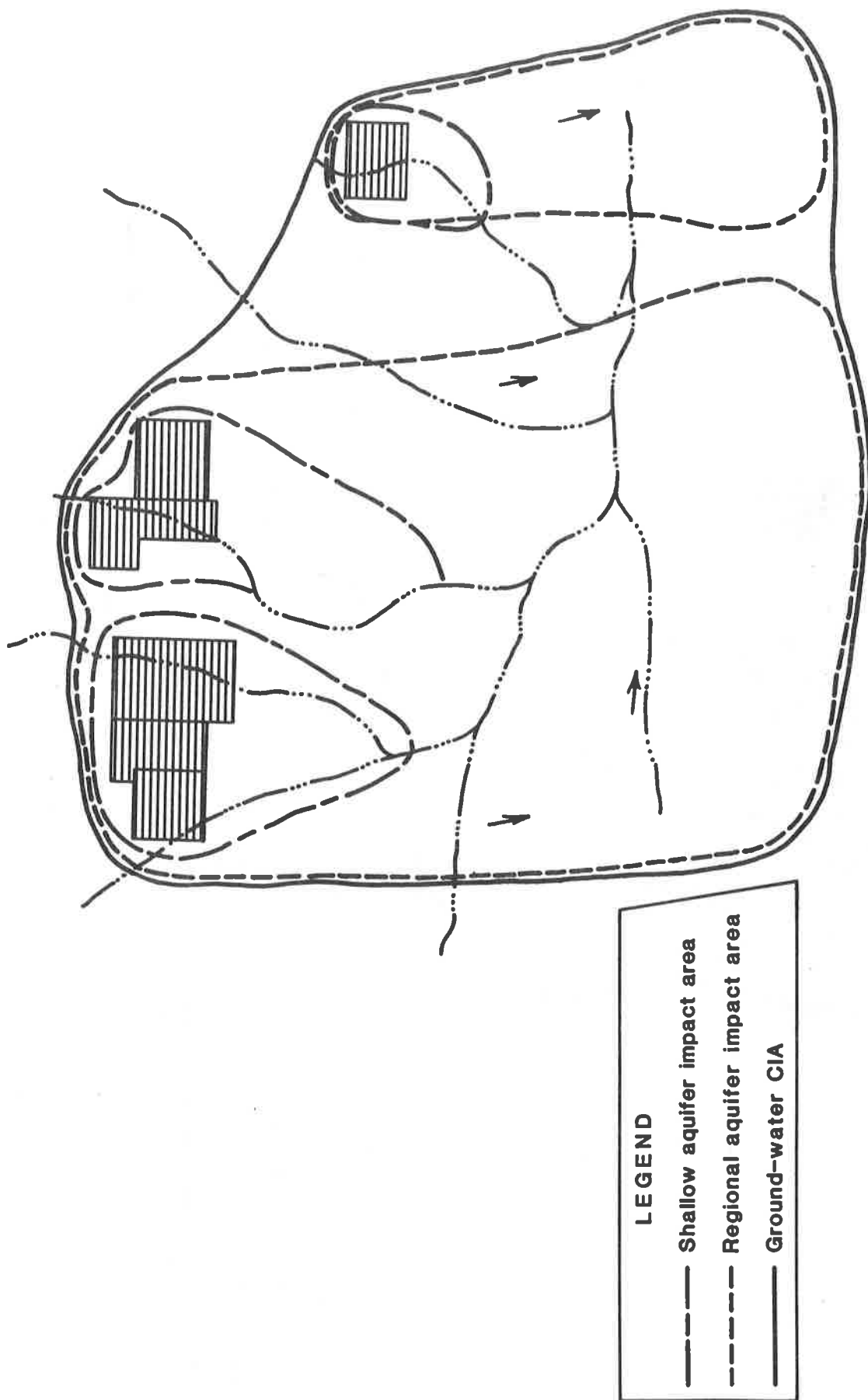


Figure IV-2.--Delineation of ground-water CIA.

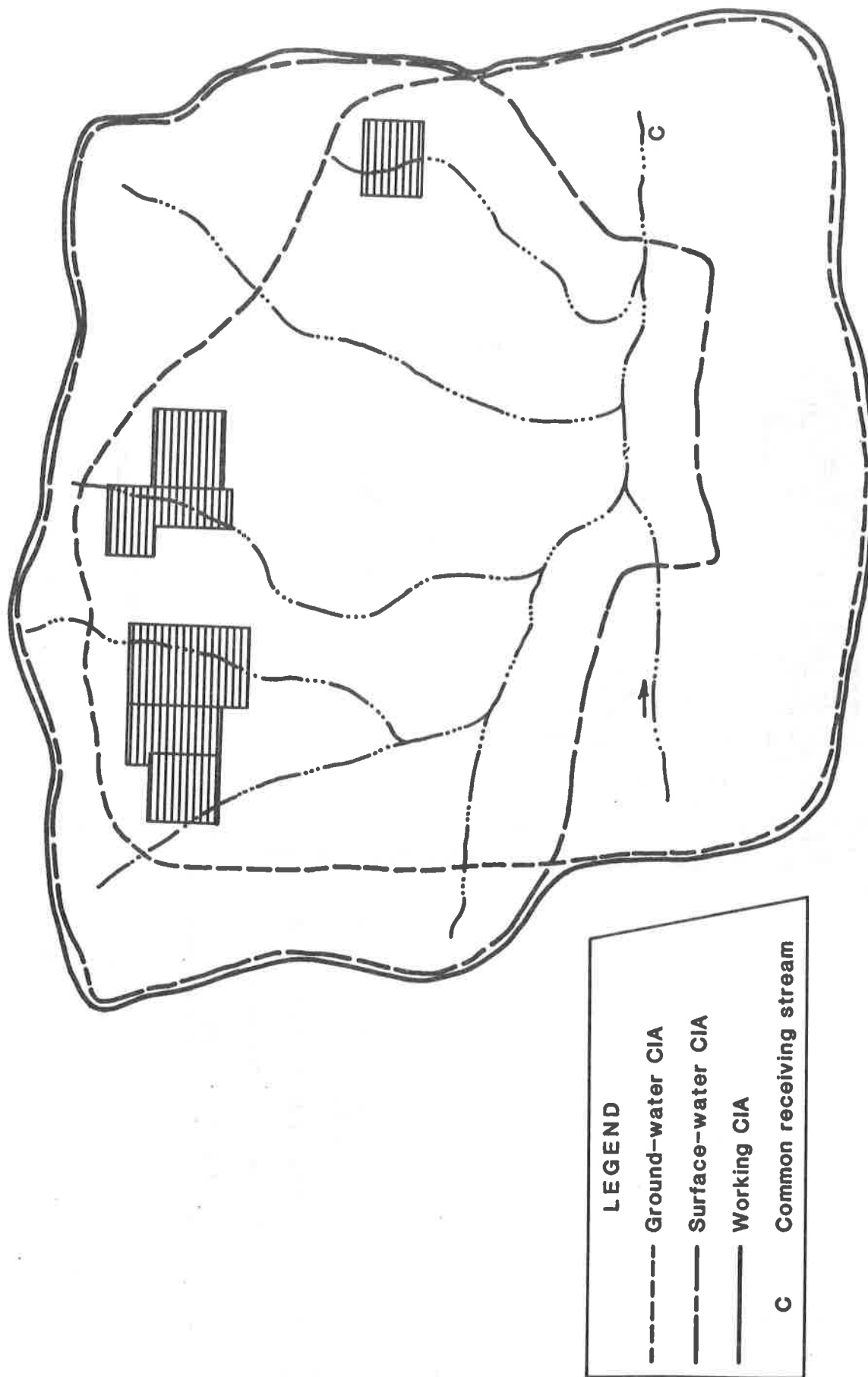


Figure IV-3.--Delineation of working CIA.

ELEMENT B. HYDROLOGIC CONCERNS

The identification by the regulatory authority of hydrologic concerns (potential problems) related to the hydrologic balance and water uses that may occur or that may be compounded by the cumulative effects of the proposed mining operation and other anticipated mining operations is the function of Element B. The concerns identified in this element must have definable parameters so that material damage criteria may be established (Element D). The determination of hydrologic concerns has great significance to the CHIA process because these factors serve to define the collection requirements for baseline data, the CHIA techniques, and the determination of material damage. It must be remembered that additional or alternate hydrologic concerns may be considered by the regulatory authority to meet area-specific needs.

Baseline data that describe the hydrologic concerns in the permit area should be available in the mine-permit application. The PHC is described in the regulations and expanded in the PHC guidance document. Most concerns will be specified in the permit application, whereas some may be implied from hydrologic characteristics of the permit and adjacent areas. These concerns can be defined from the following information: (1) the location of the source of supply for all surface-water and ground-water uses, (2) the quantity and quality of water required to meet demands related to the different uses, and (3) the geomorphic processes that might be affected by changes in the water regimens. Also, publications of State agencies commonly provide information related to local or regional problems (see appendix B.1 in the appendices volume for sources of State water-quality standards) that may be applicable to specific concerns in the cumulative impact area. A literature search may be necessary to find applicable publications.

Hydrologic concerns are an expression of problems related to water use and the hydrologic balance that may occur as a result of coal mining. In order to determine the potential impact of the problems, it is necessary to select some physical or chemical parameters that are measurable and are representative of the problems.

The interrelationships between water use, hydrologic balance, and geomorphic conditions are shown in figure IV-4. Many of the hydrologic concerns that are identified will relate to more than one of the three listed factors. For example, flow rate can be related to water availability, seasonal variation, and channel erosion. The regulatory authority's objective is to identify quantity and quality parameters that will protect water use and the hydrologic balance and maintain geomorphic stability. Each factor should be considered separately.

Each water use should be identified in the cumulative impact area with the various types being grouped together. For example, irrigation uses will require water at about the same time and of the same quality. The quantity is usually related to flow rate and volume consumed per acre. The quality parameters for irrigation are usually total dissolved solids, sodium-adsorption ratio, and toxic elements, such as boron. The crops that are grown may have to be identified with respect to toxic element sensitivity in the impact area and would, therefore, have an impact on defining the cumulative impact area in Element A. Industrial and domestic water uses are quantified by diversion requirement and quality. Usually, domestic requirements are more restrictive than industrial. Domestic standards

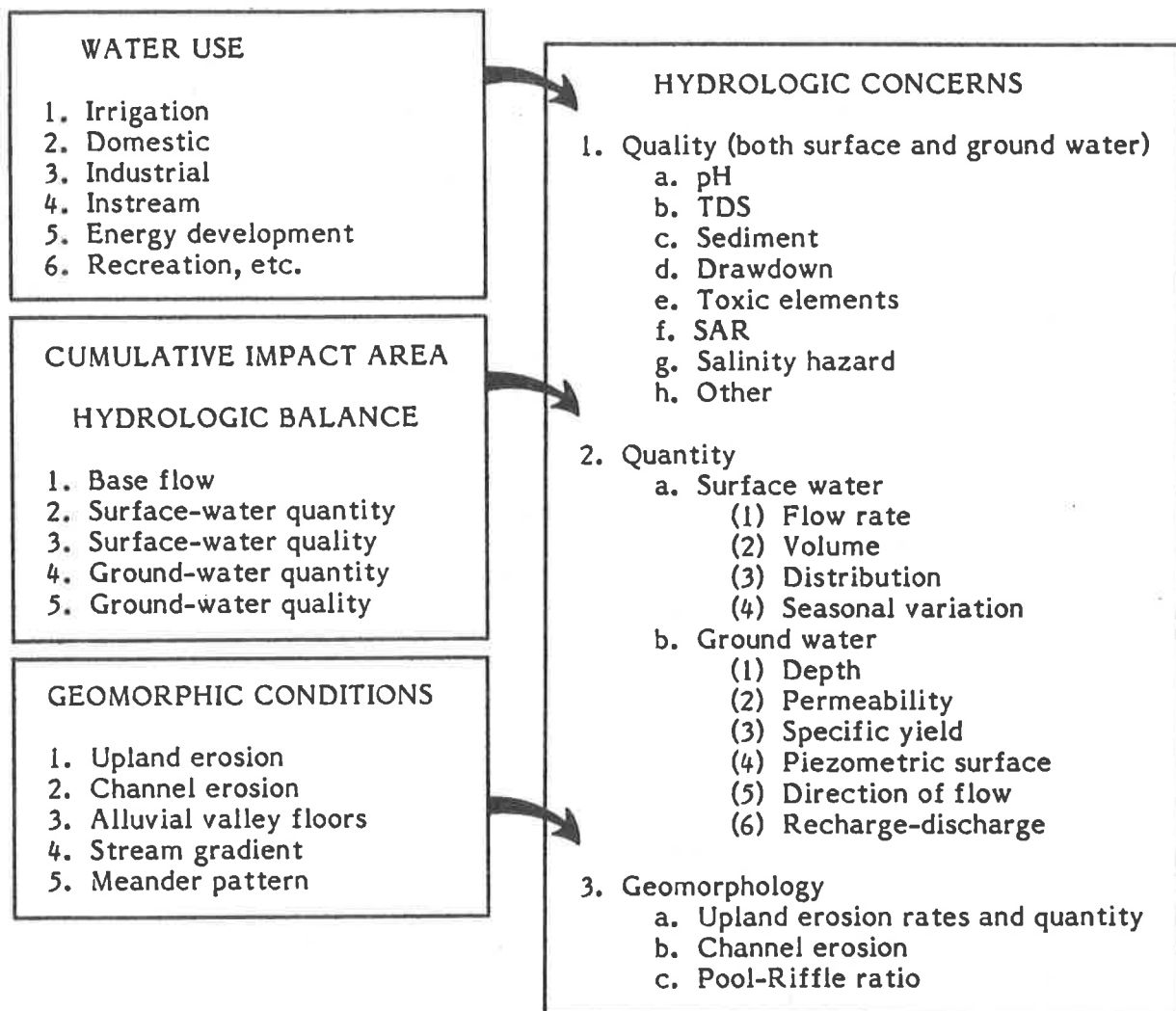


Figure IV-4.--Potential hydrologic concerns as related to cumulative impact area characteristics.

relate to total dissolved solids, sulfates, nitrites, radioactivity, hardness, sediment, pH, Fe, Mn, and bacterial quality. Usually mining will not impact on the bacterial quality and radioactivity of water. Instream use usually requires a certain minimum flow before adverse impacts occur.

Instream uses, such as fish propagation, may also limit maximum temperature and pH ranges. These values are dependent upon species present. Unique situations may require other considerations, such as have been determined by the U.S. Fish and Wildlife Service for endangered species in the Upper Colorado River basin. They have determined that any withdrawal of water constitutes material damage to the Colorado River squawfish and the humpback chub. They have also specified a way that the impacts can be mitigated at this time to allow continued withdrawals from the streams.

The hydrologic concerns differ greatly in the different coal regions of the United States. This is because the potential impacts of coal mining are dependent on the hydrologic conditions, such as rainfall amounts, temperature, water uses, geomorphic conditions, and geology. For example, typical hydrologic concerns in areas associated with the coal fields of Western United States may include but not be limited to the following:

1. Reductions in the quantity of available surface water and ground water may be critical because existing supplies in the region are relatively scarce and commonly are completely appropriated under State water rights administration. Available supplies may be reduced as a result of changes in surface runoff conditions or lowering of ground-water levels. Beneficial changes can also occur, such as reducing runoff peaks through increased infiltration and increasing base streamflow through increased ground-water discharges.
2. Increases in total dissolved solids (TDS) or sodium-adsorption ratios (SAR) in surface water or ground water may cause critical production losses where supplies are used in irrigation of crops.
3. Increases in the concentration of total suspended solids (TSS) may cause destruction of aquatic habitat or the loss of reservoir storage capacity due to siltation.
4. Changes in flow rates or suspended solids load of a stream can change the erosional balance, which may cause geomorphic instability. The adverse impact may be lowering of ground-water levels because of the downcutting of channels acting as drains which result in the ground-water level being lowered below the plant rooting depths.
5. Changes in water quality may be critical where an increase of one constituent may adversely affect water uses, such as increased concentrations of boron, selenium, iron, or manganese.

Some examples of hydrologic concerns included in the CHIA for areas in Western United States are as follows: (1) Operations of coal mines in Wyoming would lower the ground-water level and reduce the yield from domestic and livestock wells, and (2) mining operations in the Yampa River basin of Colorado would increase the total dissolved solids in streamflow due to the increased

concentrations in surface runoff and in ground water draining from the disturbed areas. These impacts must be assessed, as discussed in Element E, and evaluated for material damage, as discussed in Element F. These are many of the concerns that must be considered by the regulatory authority.

Typical examples of hydrologic concerns in areas associated with coal mining in the Eastern United States may include but are not limited to the following:

1. Changes in the chemical composition of streamflow due to the addition of acid mine drainage (e.g. total iron, total manganese, and pH) may cause deleterious effects in water used for public supplies and maintenance of aquatic organism populations.
2. Increases in the sediment load from the disturbed areas of mines may cause destruction of aquatic habitat in streams and ponds.
3. Changes in conditions affecting surface-water runoff may add to the flood hazard of a watershed.
4. Disturbances of overburden due to mine excavation may increase the availability of some chemical constituents that cause deleterious effects in water (e.g., total iron, manganese, aluminum, total dissolved solids, etc.).

An example of hydrologic concerns included in the CHIA, for mining along the Shavers Fork River in West Virginia, focused on a set of conditions (acidity and iron) that related to probable degradation of the chemical quality of surface water. These parameters were identified as being critical to fish production.

These are typical hydrologic concerns and include only a small number of possibilities. At each specific site and cumulative impact area, the hydrologic concerns must be determined on the basis of water usage in the area, existing water-quality standards, and local hydrologic conditions.

When the hydrologic concerns are being defined for a specific impact area, it is recommended that an inventory be made of all water uses which includes identification of sources, quantity and quality requirements, quality, type of use, and any known or existing water related problems. Water-quality standards and water-quantity requirements associated with the identified water users should also be evaluated. This type of approach provides an effective means of determining the hydrologic concerns that are important in terms of protecting the hydrologic balance and associated water uses. A similar inventory should be made regarding the geomorphic characteristics important to water uses that may be impacted by mining, such as alluvial valley floors, riparian zones, pool-riffle ratio, and sinuosity.

Table IV-1 has been included as a quick check to determine whether proper information has been evaluated to identify hydrologic concerns for the cumulative impact area identified in Element A. If this process is followed by the regulatory authority, it should protect the water resource values with respect to use, as

affected by water availability and water quality. The information presented in table IV-1, although not an exhaustive list, is an example of some of the steps the regulatory authority should complete in order to identify the hydrologic concerns. It may be expanded or reduced to suit area-specific conditions and considerations.

Table IV-1.--A partial list of types of information to define and evaluate hydrologic concerns

1. Define and quantify existing and projected water uses related to:
 - a. Available surface-water supply.
 - b. The quality of surface water in the basin.
 - c. Available ground-water supply.
 - d. The quality of ground water in the basin.
2. Describe existing and potential hydrologic problems related to:
 - a. Concerns identified in mine-permit application.
 - b. Concerns identified in previous CHIA studies.
 - c. Problems identified in regional studies by State agencies.
 - d. Water-quality problems that could be created by the chemistry of the overburden.
 - e. Changes in runoff characteristics that cause geomorphic instability.
3. Select representative parameters for quantifying hydrologic concerns in order to evaluate changes and assess impacts on the hydrologic balance.

Table IV-2 contains the hydrologic concerns for a hypothetical example for the Black Hole mine. It lists the hydrologic concerns, the physical or chemical characteristics, and the specific parameters to use as a measure of the impact with respect to material damage. Procedures for identifying material damage threshold values are presented in Element D.

EXAMPLE OF SET OF PARAMETERS TO BE USED
TO EVALUATE HYDROLOGIC CONCERNS

Table IV-2.--Hydrologic concerns for Black Hole example mine CHIA

Concern	Physical-chemical characteristics	Specific parameters
Surface water		
Damage to fishing stream	Mean flow Low flows--rate and duration Temperature Alkalinity, acidity, pH Suspended solids Salts	Mean monthly discharge. 7-day, 10-year discharge (7-Q ₁₀). Degrees Celsius. CaCO ₃ equivalent, pH. Concentration at 7-Q ₁₀ . TDS, sulfate ion.
Reservoir--fishing and irrigation	Stream inflows Alkalinity, acidity, pH Sediment Suspended solids	Minimum annual volume. CaCO ₃ equivalent, pH. Annual volume. Concentration during storm inflow.
Ground Water		
Municipal wells	Water level in aquifer A Water level in aquifer B Salts	Percent of baseline saturated thickness. Percent of baseline saturated thickness. TDS.
Geomorphology		
Potential upland headcutting	Hillslope gradients Channel gradients	Average slope, percent. Maximum slope, percent.

ELEMENT C. BASELINE HYDROLOGIC INFORMATION

The assembly and evaluation of hydrologic baseline information by the regulatory authority is the function of Element C. The purpose of this information is to characterize the hydrologic system and define imposition of changes by the proposed mine operation. Much of the needed hydrologic and geologic information should be available in the mine-permit applications. Details of collecting and assembling these data are discussed in "Guidelines for a Probable Hydrologic Consequences Determination." Additional baseline data needed for parts of the cumulative impact area outside the permit boundaries must be obtained from other sources, such as the U.S. Geological Survey publications or other Federal and State data collection agencies. With the data presented in the PHC portion of the individual mines and other available data, the regulatory authority must be able to describe the hydrologic system sufficiently to understand the ground-water and surface-water interactions with respect to "anticipated mining" and the hydrologic concerns identified in Element B. The description should at a minimum describe the components of the hydrologic balance that must be protected. The baseline data should provide a basis for assessment of mining impacts with respect to the hydrologic concerns and be used to determine material damage. Establishment of material damage values or thresholds for the hydrologic concerns is covered in Element D.

Appendix C.1 provides potential sources of data from each State that may be useful to the regulatory authority to supplement baseline data contained in the PHC portion of the permit application. Data from outside the permit areas necessary to perform the CHIA must be available to the regulatory authority. For this reason it is essential for each regulatory authority to identify available hydrologic data associated with coal-producing areas of the State. When additional baseline data are required but are not site specific or are not contained in the permit applications, they must be obtained from other available sources, such as Federal and State agencies. The needed baseline data may also be provided by the mining company to expedite permit processing. These data requirements need to be identified as early as possible in the permitting process. It is essential that the information be sufficient to clearly define the hydrologic system, provide required data for analysis of the impacts, and provide a sound basis for assessment of material damage.

Data availability can be a major factor in selecting downstream boundaries of cumulative impact areas. For example, a long-term USGS stream-gaging station that collects both quantitative and qualitative data would provide good baseline data and control for the assessment of impacts. Additionally, the regulatory authority can use future data collected at the station as a check to evaluate the accuracy of the CHIA's and to monitor actual impacts of mining with time. The shorter periods of records collected at the minesites can be correlated with the longer records. These correlations can be used to describe the seasonal variation and to project both high- and low-flow values.

The duration and frequency of sampling required for baseline data should be based on the hydrologic concerns and the variability of the data. For example, streamflow changes rapidly during intense rainfall events. Usually, water-quality parameter values change with the discharge. Hydrologic data covering these situations are important to the understanding of the hydrologic balance of the cumulative impact area for determining the cumulative impacts.

Baseline data required to define surface-water systems commonly include both quantitative and qualitative information. In order to determine the adequacy of baseline data, it is necessary to describe the hydrologic systems in the cumulative impact area and to describe the type of information needed to define the functions and importance of those systems to the hydrologic balance. Existing baseline data from the permit application should be evaluated with respect to the methods of collection and analysis and the lengths of record. Other sources of hydrologic information also should be investigated, such as the Bureau of Land Management, U.S. Geological Survey, State Engineer, State water-quality agencies, etc. Apparent data deficiencies with respect to coverage, period of record, quality, etc., should be identified. The location and method of data collection for all planned monitoring sites set forth in the permit application should be evaluated with regard to applicability for mining and postmining information. Data related to streams may include quantitative values of average weekly or monthly flows, flow duration, flood-frequency distribution, and low flows. Data related to the quality of water in streams should include concentrations of dissolved constituents (particularly those elements or compounds having health, use, or regulatory limits that are associated with the hydrologic concerns), and the concentration and volume of suspended sediment (annual load or basin yield). Data associated with the use of surface water should include the location and rate of all diversions, the changes in diversion rights during periods of reduced streamflow, the quality standards in relation to the principal users, the rate and volume of use in relation to seasonal requirements, and the quantity of water exported from the basin. These baseline data must reflect the hydrologic concerns identified in Element B with respect to quantity and quality parameters.

Baseline data required to define ground-water systems commonly include a description of the lithologic, structural, and hydrologic characteristics of geologic units within the aquifer and overburden systems, the rate and direction of water movement as defined by the water table or potentiometric surface, the rate and direction of water movement between aquifer units or between the aquifer and associated streams, and the location and rate of recharge or discharge. Some of these baseline data may require measurement and testing, such as determining the aquifer properties of porosity, permeability, hydraulic conductivity, transmissivity, specific yield, and storage coefficient.

Data related to the quality of ground water generally includes the concentration and areal distribution of dissolved constituents, with particular emphasis on those elements or compounds having health, use, or regulatory limits. Additional data may be obtained for determining the quality of water contributed to the aquifer from recharge, the direction and rate of chemical transport, and the associated diffusivity, dispersivity, or geochemical reactions that could occur within the geohydrologic system.

Other data related to the use of ground water include the location and source of supply from all wells and springs, the rates of daily and seasonal withdrawals, and the quality of water in relation to the standards required by the principal users. Additional data should be obtained for determining the return flow to the aquifer or stream and the losses through evaporation and transpiration.

The baseline data should be collected at sites (ground water and surface water) located with respect to the impact areas, the anticipated mining and whether or not they can also be used as impact evaluation sites. It is imperative

that these sites be near the mining operation to reflect the hydrologic changes. Also, the points must be readily accessible for current and future data collection in order to monitor actual conditions. Data obtained at the evaluation must be reflective of the identified hydrologic concerns and must be quantifiable in terms of the criteria established for material damage. When future monitoring data are available for comparison with estimated values, verification of results can be used to improve the predictive capabilities of the regulatory authority.

Tables IV-3, IV-4, and IV-5 have been included for use to evaluate the adequacy of the baseline data. These tables should not be construed as providing exhaustive or mandatory lists. The regulatory authority should carefully review these tables and modify them to meet site-specific conditions. Table IV-3 covers surface water, table IV-4 covers ground water, and table IV-5 covers the geomorphic conditions that relate to erosion and stream channel stability. Both the upland and channel erosion are of concern and must be considered in the determination of material damage. The regulatory authority must determine how important the geomorphic considerations are with respect to each mining environment.

Table IV-3.--Baseline hydrologic data useful for
characterizing the surface-water system

1. Description of drainage basin in relation to runoff.
 - a. Total area, topographic relief, basin length, and average basin slope.
 - b. Precipitation records that include monthly or seasonal data for snow pack accumulation and rainfall.
 - c. Geologic characteristics that affect runoff or streamflow.
 - d. Chemical and physical properties of the overburden.
 - e. Soil characteristics from soil surveys with respect to infiltration, runoff, and erosion.
 - f. Summaries of vegetation types and land use.
2. Description of streamflow characteristics.
 - a. Type of streams (perennial, intermittent, or ephemeral).
 - b. Streamflow data collected and tabulated to describe mean annual and mean monthly discharges.
 - c. Streamflow related to frequency and duration of floods to include:
 - (1) Floods of 2-, 10-, 25-, and 100-year recurrence.
 - (2) Flows of different frequency and duration for structure design.
 - d. Nature of frequency and duration of low flows related to water use:
 - (1) Quantitative diversion rights.
 - (2) Low-flow water quality related to stream standards and water user needs.
 - (3) Annual low flows and period of occurrence.
 - (4) Relate low flows to normal base, mean annual, and high flows.
 - e. Water quality characteristics with respect to seasonal flow:
 - (1) Major ions (Ca, Mg, Na, K, HCO_3 , CO_3 , Cl, SO_4 , TDS).
 - (2) Trace elements (Fe, Mn, As, Hg, B, Pb, Zn, Ag, Cu, Cr, Ba, etc.).
 - (3) Other (temperature, pH, suspended solids, settleable solids, bacteria)

Table IV-4.--Baseline hydrologic data useful for
characterizing the ground-water system

1. Physical description of aquifer (or aquifers) in relation to the geohydrologic framework of the area.
 - a. General description of aquifer units in relation to other stratigraphic units.
 - b. Physical description of aquifer and associated confining beds as indicated from test holes, drillers' logs, and geologic maps to include:
 - (1) extent, (2) thickness, (3) lithology, (4) structure, and (5) type of rock.
2. Hydrologic description of aquifers
 - a. Description of aquifer in terms of well yields and water use.
 - b. Description of confined or unconfined aquifer conditions.
 - c. Definition of water table or potentiometric surface as determined from test holes and observation wells.
 - d. Delineation of saturated thicknesses, direction of water movement, and areas of recharge and discharge.
 - e. Determine gain or loss of base flow in streams in relation to associated ground water.
 - f. Water movement between aquifer units and between the aquifer and streams.
 - g. Aquifer properties determined by testing that include porosity, permeability, hydraulic conductivity, transmissivity, specific yield, and storage coefficient.
3. Chemical properties of water in the aquifer.
 - a. Major ions (including Ca, Mg, Na, K, HCO_3 , CO_3 , Cl, SO_4 , TDS).
 - b. Trace elements (including Fe, Mn, As, Hg, B, Pb, Zn, Ag, Cu, Cr, Ba, etc.).
 - c. Other (temperature, pH, bacteria).
4. Characteristics of overburden
 - a. Physical destruction of resistant rocks into an erodible aggregate.
 - b. Potential chemical constituents from the disturbed overburden that may affect the water quality (acidity, alkalinity, salinity, and other toxic elements).

Table IV-5.--Baseline hydrologic data useful for
characterizing the geomorphic stability

1. Basin characteristics related to sediment discharge.
 - a. Description of basin in terms of area, length, slope, etc.
 - b. Describe geologic characteristics that affect runoff and sediment yield.
 - c. Summarize the type and extent of different soils with respect to erodibility.
 - d. Summarize the type and extent of vegetation and land use.
 - e. Describe channel conditions prior to mining (bedrock bottom, stream bottom, armored, bank conditions, riparian, etc.)
2. Stream characteristics related to sediment discharge.
 - a. Type of stream (perennial, intermittent, or ephemeral) in relation to general flow characteristics.
 - b. Define nature of flow related to frequency and duration of 2-, 10-, and 25-year floods.
 - c. Describe such stream channel characteristics as width, depth, gradient, sinuosity, etc.
 - d. Obtain samples of suspended sediment and bed load related to a broad range of stream discharges.
 - e. Estimate hydrologic characteristics of ungaged streams on the basis of channel geometry (methods have been described by USGS for most Western coal areas).
3. Erosion and sediment potential in mined areas:
 - a. Describe probable effects of erosion and sediment yield during the mining and reclamation phases.
 - b. Estimate flow and sediment yield from 2-, 10-, and 25-year floods for design of sediment control structures.
 - c. Relate proposed drainage design to geomorphic stability of mined areas after reclamation.

ELEMENT D. ESTABLISHING CRITERIA FOR DETERMINATION OF MATERIAL DAMAGE

Section 507(b)(11) of the Act requires a determination of probable hydrologic consequences caused by mining and reclamation operations, both on and off the minesite. However, the CHIA process for permit approval or denial under Section 510(b)(3) of the Act requires that these impacts be evaluated to determine whether the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area. Therefore, the regulatory authority must have and must include in the assessment report the criteria by which the potential for material damage can be assessed. These criteria are needed for comparison with the quantitatively or qualitatively predicted impacts of mining that will be obtained through the process outlined in Element E. The product of Element D will be a set of site-specific values for selected parameters used to measure the material damage at each of the predictive points identified in Element B. The criteria should be established prior to completing the projection of impacts in Element E.

There are two bases for the development of these criteria. One is the evaluation of material damage in terms of the effects on the hydrologic system. For instance, a logical extension of the discussion of hydrologic balance concepts (Chapter III) would be to define material damage in terms of the statistics of the premining relationship (A in fig. III-3). For example, if the increment of change from premining to postmining conditions exceeds one standard deviation, the regulatory authority may determine that that change constitutes material damage. The regulatory authority may determine that some other deviation is a more appropriate threshold. Another example would be to express material damage in terms of the proportional disturbance of the cumulative impact area (i.e., material damage will occur if more than a defined percentage of the area is disturbed). Basing material damage criteria on the characteristics of the system is a plausible approach, but it may present difficulties in establishing workable criteria.

The other, more obvious approach is to establish material damage in terms of specified water uses. It is a common regulatory practice to focus on designated uses. However, material damage criteria based on water use should consider both instream and out-of-stream requirements. This means that water-contact recreation, fish habitat, and the needs of aquatic organisms must receive equal consideration with industrial, domestic, and agricultural uses. Although either approach is acceptable, and in some cases the use of both may be desirable, regulatory authorities will probably base material damage criteria on water use considerations.

Discussion of Procedure for Defining Material Damage Criteria

The material damage criteria, of course, cannot require less than the existing laws, standards or regulations. Therefore, the **first step** in developing these criteria is to assemble all existing standards and determine which apply to the cumulative impact area and to the identified hydrologic concerns. Most established standards relate to water quality and its effect on specific uses. Water quantity generally is regulated through water rights laws.

On the Federal level, the Environmental Protection Agency is the major source of standards on water quality. At the State level, several agencies may

have established standards relating to water quality, rights and use. Appendix B.1 in the appendix volume lists the primary agencies in each State that are possible sources of existing water-quality standards. Counties and cities may also have established standards for water protection and use, especially in metropolitan areas, and should be considered a possible source of existing water standards. It may be expedient to develop an exhaustive listing of standards during the initial cumulative hydrologic impact assessment so that subsequent impact assessments would require only the addition of newly established or modified standards.

After all of the applicable water use standards that apply to the cumulative impact area have been assembled, it should be determined which of the hydrologic concerns and associated parameters identified in Element B are **not** covered by these standards and which concerns are only partially covered. Also, it may be determined that some of the existing standards are not as stringent as the regulatory authority deems necessary, thus requiring new standards. At this stage, it is assumed that the identified concerns and associated parameters address all the required and desirable aspects to be assessed in the hydrologic system, particularly ground-water and surface-water quality and quantity, and any concerns for the geomorphic stability of the cumulative impact area.

The **second step** of Element D is the development of criteria for the concerns that are not adequately covered by existing standards. In any given region, standards for an identified concern may be lacking. Concerns that are most likely to lack standards are those relating to ground water and geomorphology. Few States have standards that apply to ground water, and probably none have standards that apply directly to geomorphology. Because entities other than the SMCRA regulatory authority may be trying to resolve many of the same issues (such as agencies that regulate sanitary landfills and toxic waste disposal areas), such agencies should be contacted for suggestions regarding the development of needed criteria. In fact, it would be advisable to develop a statewide policy on protection of hydrologic resources prior to the time specific standards are needed. Then all State-developed standards would have a common basis, which would minimize the possibility of conflict between material damage criteria and the requirements of other regulatory agencies.

One of the more difficult and crucial tasks in the CHIA process is the development of material damage criteria for concerns that have no existing standards, or for which existing standards are not sufficiently comprehensive or stringent. These criteria should be developed cautiously because they may become precedents for establishing the State or areawide standards. Because the criteria must be tailored to regional needs, only general guidance can be provided here.

SMCRA specifically requires the assessment of cumulative impacts "particularly upon water availability * * *" (Section 507(b)(11), and by implication requires that the available water be of adequate quality for the uses designated by the regulatory authority. Development of criteria for limiting changes in surface water discharges commonly will be based on use requirements that are specified by existing water rights. The quantity requirements should consider the probable postmining uses and existing uses, including instream uses and the variation of water quantities used throughout the year. The effects of changed discharge regimes on channel stability also should be considered. Increases in peak discharges may create a flooding potential that could result in channel degradation. On the other hand, a diminished flow regime may cause sediment deposition in

stream channels, an undesirable condition for most instream water uses. On the assumption that water rights require approximate maintenance of premining water quantities and that increases or decreases in stream discharges may cause changes in channel morphology, material damage criteria should be designed to maintain the flow regime within a small percentage of the baseline quantities.

The major concerns about the cumulative impacts of the mining on ground-water availability tend to focus on the maintenance of streamflows and pumping requirements. The drawdown of the potentiometric surface in the vicinity of the mine is a common impact of mining on the ground-water system. Thus, it is logical to express material damage criteria for ground-water quantity in terms of the potentiometric surfaces affected. Because high water tables also can cause problems in some areas, the criteria may need to address both rises and declines in the potentiometric surface. The development of these criteria then becomes a matter of determining how much change in the potentiometric surface can be sustained without causing material damage to the hydrologic balance of the ground-water system.

Although ground water and surface water are presented as separate entities in this guidance document, it is imperative that the relationship between them be understood and considered in setting limiting criteria. Some items that should be considered are the interrelationships of surface and ground water, long-term rate of recharge to the aquifers, rate of recharge to the reclaimed spoils, rates of recharge relative to rates of use, and the possible impedence of ground-water movement by the reclaimed spoil material.

The increased public concern during the past decade and a half for the quality of the nation's water supplies has led to the establishment of water quality standards by various regulatory agencies. These standards generally are based on the maintenance and protection for specified water uses. Although standards for surface water are most numerous, some States also have established standards for protection of ground water. Material damage criteria for both ground-water and surface-water quality can be developed, in many cases, from existing standards; several sources of information are available to the regulatory authority for guidance. The regulatory authority in nearby States may have established standards for similar concerns. Another source of information is a compilation by McKee and Wolf (1963) regarding the water-quality criteria promulgated by State and interstate agencies as well as legal application of such criteria. Also, EPA (1976) has provided information on the toxic levels of many water polluting substances relative to specific uses. In situations where the aquifer discharges into the surface stream system, the effects of this discharge on the quality of surface flows should be considered in developing ground-water material damage criteria.

Geomorphic concerns probably will focus on channel and hillslope erosion most often. The most likely areas of cumulative concern are increased sediment loads in the streams, the possibility of channel downcutting with its attendant dewatering of alluvial aquifers, and dissection of the land surface with gullies. Criteria for addressing these problems probably should focus on limiting channel and hillslope gradients in the reclamation areas. Hillslope gradients which are within approximate original contour requirements (30 CFR 816.100-106) may not be adequate in terms of erosion potential. In the Western United States, landscapes commonly are carved in layers of erosion-resistant rock that keep stream gradients relatively steep. After the mining process breaks up these

supporting layers into a variety of smaller fragments, stable gradients for both hillslopes and channels are likely to be different from the premining gradients. The material damage criteria must assure erosively stable slope gradients relative to expected postmining conditions (i.e. vegetative cover, particle-size distribution of reclaimed overburden, etc.).

Step three involves establishment of criteria for any aspects of material damage assessment that have not been categorized. A possible example of this type is the consideration of whether incremental change limits are needed for some parameters.

There is a possibility that the impacts of a single mining operation may "use up" the total allowable change from baseline levels to the maximum allowable limit. To prevent this possibility, it may be necessary to set incremental change limits for some parameters. However, actual changes should already be at a minimum if the permitted operations are, in fact, designed to minimize the impacts to the hydrologic balance, as required by the regulations.

The nature of other hydrologic concerns may dictate that limits be set on the time-rate of change of certain parameter values. For example, some species of aquatic life may be able to survive relatively high water temperatures, but the rate of change of the temperature must be commensurate with the organisms ability to acclimate to temperature changes. The acclimation rate will differ with species and rate-of-change limits may be necessary to assure survival of the specific species. Dissolved oxygen content is another parameter for which rate-of-change limits may sometimes be necessary. The need for both types of incremental limits should be considered in the process of developing material damage criteria.

Step four of Element D suggests that the regulatory authority the design of a specific set of material damage criteria for each evaluation site identified in Element B. Site-specific criteria are necessary because each site could have a different set of conditions to be evaluated. The design of these criteria sets should be a relatively simple part of the process if Steps 1 through 3 have been properly completed. EPA (1983, Chapter 11) has published guidelines for deriving site-specific water quality criteria. The regulatory authority may wish to use these EPA guidelines to develop site-specific material-damage criteria, or to use them as a pattern for its own guidelines. The product of this step and of Element D is a listing of the material damage criteria for each parameter identified at each evaluation site.

Once criteria have been established for the coal-producing areas of a State, they should be applicable to subsequent CHIA's without additional developmental effort. Periodic review and updating should assure that the correct criteria are available at any time.

Procedure For Defining Material Damage Criteria

The following steps are suggested as a process for establishing material damage criteria:

1. Assemble existing State, Federal, and local standards which apply to the expressed hydrologic concerns (product of Element B).

- a. Source of standards.
 - (1) U.S. EPA.
 - (2) State agencies.
 - (3) City and county agencies.
 - b. Identify parameters not adequately addressed by existing standards by comparing existing standards and identified parameters.
2. Develop limiting values for parameters associated with hydrologic concerns not covered by existing standards.
- a. Water quantity.
 - (1) Consider any quantity change defined by applicable water rights.
 - (2) Consider needs of probable uses.
 - (3) Consider possible channel stability problems resulting from discharge changes.
 - b. Water quality.
 - (1) Consider standards used by surrounding States.
 - (2) Consider quality requirements for present and potential uses.
 - (3) See U.S. EPA (1976) and McKee and Wolf (1963) for suggested limits of specific constituents relative to use.
 - c. Geomorphology
 - (1) Consider need for reduced channel and hillslope gradients in the postmining environment.
3. Develop any additional criteria considered necessary for an adequate assessment of material damage.
- a. Need for incremental change (or time rate of change) limits.
4. Establish a site-specific set of material damage criteria for each predictive point identified in Element B. These sets of criteria are the product of Element D.
- a. Apply appropriate criteria from lists developed in Steps 1 through 3.

ELEMENT E. ANALYSIS OF CUMULATIVE HYDROLOGIC IMPACTS

Analysis of the hydrologic system with the imposed stress of the anticipated mining to determine its probable impacts and their magnitudes is the goal of Element E. More specifically, the regulatory authority's task involves estimation of the magnitudes of changes that the indicator parameter values can be expected to experience as a result of mining. Accomplishment of this task may best be achieved by first selecting an analytical approach, then selecting the specific techniques and methodology to be used, and, finally, making the analysis.

Two basic analytical approaches have commonly been used to date in the development of CHIA's. One approach is to combine the results (estimated values of indicator parameters) presented in the PHC portions of individual mine plans into composite impact values for the CIA. Use of this approach requires the regulatory authority to develop PHC's for any "anticipated mining" operations for which PHC's are not available (leases, 2-acre exemptions, etc.). The other approach is to make an independent hydrologic analysis of the CIA, using the data provided in the permit application package and in the PHC portions of other applicable mine plans, as well as pertinent data from any other sources. In a given situation, one or the other of these approaches may be appropriately used.

The basic difference between the two approaches is **not** a difference of specific techniques used with each approach; rather, it is one of how selected techniques are applied and by whom. The PHC of each mine operation is normally determined by a different analyst using a different specific set of analytical techniques. Under the combinational approach, the actual combining of these PHC results to obtain the cumulative impacts would involve yet another set of techniques and another analyst (that is, the regulatory authority). Each analyst is likely to make his own assumptions about the hydrologic system. The combination of results obtained from such unrelated bases may invite severe criticism if not rejection. With the independent analytical approach, the same set of techniques would be applied over the whole CIA by the same analyst(s). Therefore, the independent approach could generally be expected to give the most consistent, uniform, and accurate results. From a strictly hydrologic standpoint, the independent analytical approach would be valid in all cases. Use of the combinational approach would be most appropriate early in the development of an area when cumulative impacts could be expected to be small.

Once an analytical approach is adopted, suitable hydrologic estimation techniques can be selected. If the combinational approach is used, specific analytical methods and techniques are not needed because estimates of impacts should already exist in the individual PHC's. However, suitable procedures for combining parameter values are needed because the simple addition of values is not a valid combinational procedure for some hydrologic parameters. For example, flow routing procedures are necessary for combining the peak discharges of two streams, and a discharge-weighted average procedure is needed to determine the concentrations of substances at different locations in the stream system. Therefore, for the combinational approach, the regulatory authority needs to select or develop valid procedures by which results of the individual PHC's can be combined.

If the independent analytical approach is used, then appropriate analytical methods and techniques must be selected. Technique selection depends on many

factors, but a primary consideration should be that the technique adequately account for the dominant physical processes occurring in the hydrologic system being evaluated. The required degree of accuracy is another important consideration. In some cases, a worst case analysis may be adequate. However, when values of the indicator parameters approach the material-damage threshold levels, more rigorous and accurate techniques may be needed to verify that the material damage thresholds are not violated.

Methods for predicting cumulative impacts may be classified into the following broad categories:

1. Qualitative methods.
2. Empirical equations and statistical correlations.
3. Physical process models of the hydrologic system.

Qualitative methods are those which provide for systematic evaluation of qualitative data inputs and predict a range of output values. They rely heavily on the judgment of the user, who should be a competent hydrologist and highly knowledgeable about the method and the CIA being assessed.

The second category includes a wide range of techniques, equations, and statistical correlations by which values of various hydrologic parameters, under specified conditions, can be calculated. The universal soil loss equation (Wischmeier and Smith, 1965), the Theis equation (Theis, 1935), and the Muskingum flow routing equation (McCarthy, 1938) are examples of techniques in this category. Brief discussions relative to the specific uses of these and other methods in categories 2 and 3 can be found in appendix D.1.

A complete hydrologic analysis would require application of one or more of these techniques in proper order. Thus, the Theis equation would be used to calculate aquifer transmissivity and storage coefficients from pump test data, and these parameters would, in turn, be used to calculate aquifer flow rates and the extent of drawdowns. For CHIA analysis, the appropriate methods would be systematically applied to all mine operations in the CIA, giving appropriate consideration to possible effects of adjoining operations. These calculations can be facilitated by use of programmable hand-held calculators or minicomputers. Programs for many of these methods are generally available (Croley, 1977; OSM, 1981).

The final category of techniques is comprised of hydrologic models which simulate the physical processes in the hydrologic cycle with mathematical equations. In all but the simplest hydrologic systems, the equations governing the system processes are either too numerous or too complicated to be solved by direct mathematics. Therefore, the high speed computational capabilities of digital computers are usually needed to solve the equations.

Models provide the analyst with a means of integrating the responses of interrelated processes of the hydrologic system. In this way, all processes of the system can, in theory, be analyzed with a single procedure. Because all components of the system are automatically and systematically considered, the model and its solutions should more nearly reflect real physical systems than does

the piecemeal application of individual category 2 techniques. However, the underlying concepts of the individual models and the availability of data are also extremely important to the analysis outcome. In any case where the data base is extensive enough to allow adequate calibration and verification of the models for each set of watershed conditions to be modeled, then physical process models should give excellent results and their use should be strongly considered for that particular CHIA analysis.

Hydrologic models have been designed to accomplish a wide variety of analyses. To date, the need for a single model that analyzes all aspects of the hydrologic cycle has been limited. The complexity of such a model would tax the computational abilities of even today's high-speed computers. Therefore, most physical process models are limited to a particular segment or segments of the hydrologic cycle. Some model the surface-water processes; others, the ground-water system. Still others deal with water pollutants and their transport through the system. A comprehensive surface-water model would include routines for modeling the dilution and transport of water-quality constituents, as well as the generation of upstream and upland runoff volumes and stream discharge rates.

Models also vary in the degree of capability. Some will generate water volume input (surface runoff or aquifer recharge) and route this water into and through the stream channel or aquifer systems. Others only route through the system water quantities calculated by other methods. The same alternatives are available for water quality models.

Another division of model characteristics is between long-term or continuous models and those that only simulate individual storm events. Event models simulate the effects of selected storms on a given set of antecedent conditions. Several simulations using selected antecedent conditions for critical periods of the hydrologic cycle would be necessary for a CHIA analysis. Continuous models account for the cumulative effects of precipitation, evapotranspiration, soil moisture storage, pollution buildup, and so forth; therefore, changes in antecedent conditions are automatically and continuously updated during a simulation run. A CHIA assessment done completely by modeling would require a full range of model capabilities.

Whatever techniques or combinations of techniques are selected, the analytical process must have the capability of predicting water quantity and quality changes (changes in availability) under seasonal conditions. It should also have the capability of determining magnitudes of changes and of routing those changes through the system to the downgradient boundary of the CIA. The time span for the analysis period should cover the mining, reclamation, and postreclamation phases in order to determine maximum impact magnitudes, when the maximums occur, and the rates of recession from the maximum values.

The following is a partial list of considerations that may be useful to the regulatory authority in selecting the appropriate methods and techniques for an independent analysis of cumulative hydrologic impacts:

1. Desired accuracy and precision of results.
2. Available baseline hydrologic data and information.
3. PHC analysis results for anticipated operations,

4. Previous hydrologic studies in the CIA.
5. Identified hydrologic parameters.
6. Time and resources available for the analysis.

Qualitative review of these factors by a hydrologist with experience and knowledge of analytical methods should indicate which general categories of methods are appropriate for the CIA to be assessed. Evaluation of the available hydrologic data is a critical factor, as it affects not only which specific methods can be successfully used but also the accuracy of results that can be achieved with that method. Also, each technique is based on certain assumptions about the conditions of the hydrologic system. Application to systems with conditions significantly different than the assumed conditions can seriously affect the accuracy of the technique, and this factor should be an important consideration in the selection of techniques.

A problem with many of the methods for projecting impacts occurs when the characteristics of the hydrologic system are changed by the mining. Most hydrologic prediction methods must be calibrated and verified if they are to give reliable results. Only with calibration and verification can the accuracy of a method be determined. Calibration involves adjusting fixed-value parameters until predicted outputs closely simulate or "fit" previously measured outputs of the system. Once a "good" fit is obtained, the method is said to be calibrated for the system from which the measured data were obtained. Verification involves using the adjusted parameter values with different input values for the system and comparing the measured outputs with the predicted outputs. However, if the system subsequently is altered, then the method is no longer calibrated and the accuracy of its predictions is unknown. For predicting impacts of coal mining, fixed-value parameters are usually calibrated to premining conditions. After the system is disturbed by mining, accuracy of results are unknown, unless the method has also been calibrated in a similar physiographic and climatic area under similar mining conditions. From calibrations under similar mining conditions, model parameter values can be selected to represent the mining conditions.

Use of physical process models requires sufficient data to calibrate and verify the models for each set of watershed conditions to be modeled. If a model can be satisfactorily calibrated and verified to establish parameters values for the existing and anticipated land use conditions over a physiographic region, coal region, or CIA, then this "precalibrated" model can probably be applied repeatedly within that region for a reasonable cost. However, if the model must be recalibrated for each application, its use may not be cost effective.

After selection of necessary methodology, it is applied according to good hydrologic practice and professional judgment. If results indicate that impacts extend beyond the working CIA boundary, the boundary delineation should be adjusted and the analysis modified accordingly.

Procedure for Analysis of Cumulative Hydrologic Impacts

1. Select analytical approach.
 - a. Combinational approach.
 - b. Independent analytical approach.
2. Select specific techniques and methodology.

- a. Qualitative methods.
 - b. Empirical equations and statistical correlations.
 - c. Physical process models.
3. Analyze CIA for cumulative hydrologic impacts.

ELEMENT F. DETERMINATION AND STATEMENT OF FINDINGS

The final task in the CHIA process (Element F) is to determine whether the hydrologic assessment of the CIA (Elements A-E) indicates that the additional impacts of the proposed operation may cause material damage to the hydrologic balance outside the permit area and, then, to write a statement of these findings, giving all supporting evidence and stating the rationale used. This determination is the main objective of the whole CHIA process. The supporting evidence and rationale validate the determination.

The determination may be based on quantitative comparisons and/or on qualitative evaluations. A quantitative determination is a comparison of analytical estimates for the defined indicator parameters (product of Element E) with the corresponding material damage threshold values for these parameters (product of Element D). A qualitative determination is a judgment determination by the regulatory authority based on all available evidence. For this final determination, the minimum acceptable evidence consists of an adequate PHC evaluation for the proposed operation and for each "anticipated mining" operation within the CIA. Whenever possible, the quantitative approach should be used, but qualitative determinations may also be appropriate. Regardless of whether the determination is qualitative or quantitative, the rationale for the decisions should must always be clearly stated.

Both approaches should probably be used for most determinations. Certainly, quantitative comparisons are most defensible. However, estimating future values of hydrologic parameters is uncertain at best, as is the task of clearly defining what constitutes "material damage" and what does not. For a variety of reasons, one cannot be certain of the correctness of answers provided by hydrologic estimating procedures. Also, different procedures may result in a range of values that straddle critical levels. The natural variability of hydrologic processes may necessitate that damage levels cover ranges rather than single, precise values. To make material damage determinations solely by comparison of estimated values to single-value criterion ignores the fact that natural forces are variable. Quantitative comparisons can be used, but they should not be the sole basis for the material-damage determination. The regulatory authority should use qualitative factors along with quantitative comparisons to make final material-damage determinations.

The following two-part procedure is suggested for accomplishing Element F:

- I. Determine potential for material damage.
 - A. Make quantitative comparisons of estimated parameter values with the applicable material-damage criteria assembled in Element D.
 - B. Make qualitative comparisons of the parameters for which quantitative evaluation is not appropriate.
 - C. Make the final determination of whether impacts from the proposed operation accumulated with the impacts of other anticipated operations may cause material damage to the hydrologic balance outside the permit area.
- II. Prepare a statement of CHIA findings.
 - A. Introductory information.
 - B. Documentation to justify actions.
 - C. Statement of findings.

Discussion of Procedure for Determination of Material Damage Potential

Despite the uncertainties of quantitative hydrology, it remains the most defensible means of assessing cumulative hydrologic impacts and should be used at every possible opportunity. The procedure is to compare the predicted magnitudes of the defined indicator parameters (product of Element E) to the corresponding material-damage criteria thresholds for these parameters (product of Element D). This comparison should indicate the potential for material damage to the hydrologic balance outside the permit area. Any necessary conditions for comparison should be spelled out as part of the identification of hydrologic concerns (Element B). For instance, the flow conditions under which total dissolved solids concentrations are to be evaluated should be considered as part of the information needed to characterize the concern for salt loading. The specific wording of these criteria becomes especially important when, with each additional mine, cumulative impact magnitudes approach critical levels. If damage conditions are clearly identified as part of the concern, then the material-damage criteria and the estimated values for the indicator parameters (Element E) can be stated in similar terms and units, and quantitative determinations should be relatively straightforward.

When first estimates indicate that material damage thresholds may be exceeded, the regulatory authority may wish to reevaluate the impact prediction procedures used. Some kinds of modifications to the estimating procedures may be appropriate. For example, worst case conditions are commonly assumed as a means of simplifying the estimation process. It is common CHIA practice to assume that the maximum impacts of all the mining operations within the CIA will occur at the same time. When an analysis based on this assumption indicates potential material damage, a reanalysis using the actual timing sequence of the mining operations may reduce the impact estimates to nondamage levels. Such adjustments are acceptable and proper. However, it would be difficult for the regulatory authority to justify reevaluations in which individual input parameter values are adjusted to obtain favorable output magnitudes.

Qualitative analysis may enter the process at two levels. The first is in determining the magnitudes of the indicator parameters and comparing these

values to the material damage criteria. The second is in making the final determination of whether impacts of the proposed operation accumulated with the impacts of the other anticipated operations will result in material damage to the hydrologic balance outside the permit area. In the first case (Step I.B of procedure), the analyst applies professional judgment to all available evidence, which may include analytically derived, as well as qualitative, information, to arrive at a material damage determination for each indicator parameter. In the second case (Step I.C), the regulatory authority considers the comparisons made in Steps I.A and I.B, and any other relevant factors to arrive at a CHIA permitting decision. In either case, the rationale used in making the qualitative determination is, in effect, the methodology. Thoroughly document this rationale either directly or by reference, just as analytical methods would be described, as this rationale is the primary defense against potential challenges to qualitative evaluations.

Qualitative estimates allow the regulatory authority to consider all relevant factors in making the final determination. Also, in early development stages of a coal field, while there are few operating mines and minimal impacts, qualitative evaluations may be wholly adequate. However, as the number of operations increases, increased use of quantitative procedures is recommended. But even when the CHIA is mostly quantitative, the regulatory authority should have, when making the final material damage determination, the option to qualitatively consider factors which are not amenable to the more mechanical quantitative comparison approach.

If the determination is negative (material damage to the hydrologic balance is probable), and the regulatory authority determines that no further evaluation of the determination is warranted, the negative finding is reported, granting of a permit is delayed, and the CHIA process is finished for the time being. Mitigating actions by the company to further minimize impacts of the proposed mine would be handled outside the CHIA process as part of the overall permit processing procedure (fig. II-1).

Preparation of Statement of Findings

The second part of Element F involves writing of a statement of findings with supporting evidence and rationale. This statement should describe the actions taken to complete each of the process elements, with emphasis on providing the justification for these specific actions or decisions. It should also document the assessment findings as to whether the addition of the proposed operation to the other anticipated mining will cause material damage to the hydrologic balance outside the permit area. For expediency, preparation of the written statement should be considered a part of each of the other elements, with the appropriate sections being completed as these elements are processed. In this way, the bulk of the writing will be completed when the analysis is completed. Then, at Element F, the statement would only require finalization and the writing of an executive summary. A suggested form and content for the CHIA document is given in Appendix A.

At a minimum, the statement should cover three broad topics. The first is introductory information, which should include why this specific CHIA is necessary (new application, modification, and so forth), and a very brief statement of other mining activity in the immediate area. It should mention any previously prepared CHIA's for the area that are incorporated in the present effort, and it should

specify any significant difference between approaches used in the present and previous efforts. The statement should also include any information of a general nature that adds to the understanding of the situation and conditions dealt with in this CHIA.

The second is a thorough discussion of actions taken in the evaluation of each element. This discussion will comprise the bulk of the statement and should reflect how the assessment was done and the reasons for specific actions and decisions. The discussion of each element should touch on three basic points:

1. It should document all parts of the analysis that are significant to the outcome of the element product. A partial list of appropriate topics would include the analytical approach used to evaluate the element, the specific methods used, assumptions made, specific parameters used or excluded, appropriate maps and illustrations, description of the portion to the system being analyzed, any exceptions made to the normal procedure, and applicable statutory and regulatory requirements. Any topic necessary to convey what actions were taken in the evaluation of the element and how they were accomplished should be included in this discussion.
2. The discussion of each element should emphasize the justification for each specific decision made during the evaluation of the element. The justification of decisions is an integral facet of the CHIA process. The rationale for using one option over others, and exceptions to normal procedure should be thoroughly documented. Any decision or action may be challenged in the subsequent phases of the permitting process; therefore, the regulatory authority should have legally and scientifically valid reasons for those actions.
3. The discussion of each element should include an illustration or listing of the product resulting from the evaluation of the element. The desired element products have been described in this guidance document in the discussions of the individual elements. For example, a map showing the delineation of the CIA should be a standard illustration for Element A of these statements. The locations of evaluation sites, a partial product of Element B, should also be shown on this map. The listing and discussion of the element products should clearly describe those products and their use to the remainder of the assessment.

The final topic to be addressed in the findings statement is a statement of conclusions and the findings relative to the potential for material damage to the hydrologic balance. This finding is the ultimate objective of the assessment. The discussion should summarize the major reasons for the finding and state any special conditions or stipulations that the finding is contingent upon. Any significant differences from previous CHIA's in the area and the probable reasons for the differences should be noted. Upon completion of the statement, an executive summary should be prepared for general use and for inclusion in the permit application package.

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APPENDIX A

RECOMMENDED CHIA REPORT CONTENT

The final product of the cumulative hydrologic impact assessment is a report that fully documents all aspects of the study and its findings. The report must stand alone without the permit application or the permit decision document. The outline that follows suggests a generally acceptable list of contents for a CHIA report. However, it may not include all items that require discussion for a particular study. The exact report contents are site dependent, and, therefore, this outline should be modified as necessary. However, report topics should include all the major steps of the CHIA process. The report should, among other things, thoroughly describe the subject hydrologic system, discuss the adequacy of the data set used, provide the rationale for delineation of the CIA, state hydrologic concerns for the CIA, describe and justify the methods and techniques used, define damage criteria, and generally document and justify each decision made in the course of the study and each conclusion drawn from the study.

REPORT CONTENT

(Note: Materials shown in parentheses indicate the types of items that should be discussed under the indicated topic headings.)

- I. Executive summary
- II. Introduction
- III. Discussion of CHIA process elements
 - A. Cumulative impact area
 - 1. Maximum upstream and downstream extent of CIA
 - (a. Discuss criteria used to evaluate significance of spatially remote operations)
 - (b. Discuss application of criteria and resulting CIA extremes)
 - c. Delineate watershed area between these points on suitable map.
 - 2. Delineate watershed area between these points on suitable map
 - (a. Specify anticipated mining operations and locate on map)
 - (b. Discuss process of delineating surface-water CIA)
 - (c. Discuss process of delineating ground-water CIA)
 - (d. Show working CIA on suitable map.)
 - B. Hydrologic baseline conditions in the CIA
 - 1. Adequacy of available hydrologic data
 - a. Surface-water data
 - b. Ground-water data
 - 2. Characterize the hydrologic system
 - a. General description
 - b. Surface-water system
 - (i. Describe surface-water system)

- III. Discussion of CHIA process elements--Continued
 - B. Hydrologic baseline conditions in the CIA--Continued
 - 2. Characterize the hydrologic system--Continued
 - b. Surface-water system--Continued
 - (ii. Quantify surface flows)
 - (iii. Quantify surface-water quality)
 - (iv. Inventory surface-water usage, location, and quantity)
 - c. Ground-water system
 - (i. Describe ground-water system)
 - (ii. Quantify ground-water flows)
 - (iii. Quantify ground-water quality)
 - (iv. Inventory ground-water usage, location, and quantity)
 - C. Hydrologic concerns and associated indicator parameters
 - 1. Surface-water concerns
 - a. Identify concerns
 - (i. Discuss rationale for inclusion of each concern)
 - b. Indicator parameters used to evaluate surface-water concerns
 - (i. Discuss reasons for selection of specific parameters)
 - c. Impact assessment sites
 - (i. Discuss selection of sites where impacts are to be assessed)
 - (ii. Locate sites on map of CIA (Use map prepared in step III.A.1.c))
 - 2. Ground-water concerns
 - a. Identify concerns
 - (i. Discuss rationale for inclusion of each concern)
 - b. Indicator parameters used to evaluate ground-water concerns
 - (i. Discuss reasons for selection of specific parameters)
 - c. Impact assessment sites
 - (i. Discuss selection of sites where impacts are to be assessed)
 - (ii. Locate sites on map of CIA)
 - D. Material damage criteria
 - 1. Existing water-quality standards
 - 2. Existing water-quantity standards
 - 3. Development of limiting parameter values for concerns inadequately covered by existing standards
 - 4. Site-specific material damage criteria
 - (a. Prepare list of criteria for each parameter at each site)
 - E. Assessment of cumulative impacts of mining on indicator parameters
 - 1. Mining methods used within the CIA
 - (a. Describe the mining methods being used)
 - (b. Discuss effects of various mining methods on hydrology of the CIA)

III. Discussion of CHIA process elements--Continued

E. Assessment of cumulative impacts of mining on indicator parameters--Continued

2. Surface water

a. Predictive methods used

- (i. Discuss reasons for using these methods)
- (ii. Discuss assumptions of the methods)
- (iii. Discuss data requirements of the methods)
- (iv. Discuss procedure used to calibrate method)

b. Projected values of indicator parameters at identified surface-water impact sites--long- and short-term impacts

- (i. Discuss difference in procedure to obtain short-and long-term parameter values)
- (ii. Quantity parameters for each site)
- (iii. Quality parameters for each site)

3. Ground water

a. Predictive methods used

- (i. Discuss reasons for using these methods)
- (ii. Discuss assumptions of the methods)
- (iii. Discuss data requirements of the methods)
- (iv. Discuss procedure used to calibrate method)

b. Projected values of indicator parameters at identified ground-water impact sites

IV. Determination and statement of findings

A. Determination of material damage potential

1. Surface water

a. Comparison of projected values with material damage criteria

- (i. Discuss comparison procedures used)

b. Potential for material damage to the surface-water system

2. Ground water

a. Comparison of projected values with material damage criteria

- (i. Discuss comparison procedures used)

b. Potential for material damage to the ground-water system

B. Statement of findings

(1. Final findings

(2. Discuss reasons for these findings

V. References

VI. Appendixes

A. Baseline hydrologic data

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APPENDIX B

EXAMPLE CHIA FINDINGS REPORT

This example is offered to show the kinds of information that should be included in a CHIA findings statement. Because examples tend to simplify real conditions, they may not address all topics that should be addressed for a specific real-world site. This example is no exception. Therefore, the specific topics addressed and the specific way they are addressed should not be construed as the only ones that need to be presented, or that this is the "best way" to present them. Especially the results, conclusions, and lines of reasoning leading to the conclusions, as presented here, may not be valid for a specific real situation. Only the actual conditions of the specific CIA should govern how and what should be presented in a findings statement.

CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT FOR THE BLACK HOLE MINE

INTRODUCTION

Coalo Energy Company has submitted an application for a permit to mine its leasehold lying in portions of sections 9, 10, 11, 14, 15, 16, and 17, T. 51 N., R. 71 E., in Anchor County. This is the first permitting application for the mine, which is known as the Black Hole mine. There are two presently active mines in the immediate area (Prairie Chicken and Mud Hen), one recently completed mine (Old Crow), and several lease tracts. A CHIA was prepared approximately 1 year ago for the Prairie Chicken mine, and all applicable information from that document was used in the present effort.

DELINEATION OF THE CUMULATIVE IMPACT AREA

Maximum Possible Extent of CIA

The major river basin (river that discharges into the ocean) associated with the proposed Black Hole mine is that of the Coal River. Within the Coal River basin, coal is being mined in four widely separated areas (fig. B-1). Three of the areas are located on tributaries to the Gold River, which is tributary to the Coal River. The fourth area lies adjacent to the Coal River valley. The mines in these four areas include all operations whose impacts could possibly accumulate with those of the proposed operation.

A CHIA was conducted about 1 year ago for the Prairie Chicken mine, which is located in the same area of development as the proposed mine (Area I, fig. B-1). That assessment determined the maximum downstream extent of the CIA for the mines in Area I to be at the mouth of the Padre River (Point A, fig. B-1). The determination was based on the dilution of estimated total salt load from each of the mines in the Coal River basin. The analysis showed that the increased salt load in the Coal River at Point C would be less than the error inherent in methods available for measuring total salt loads. Therefore, it was concluded that the

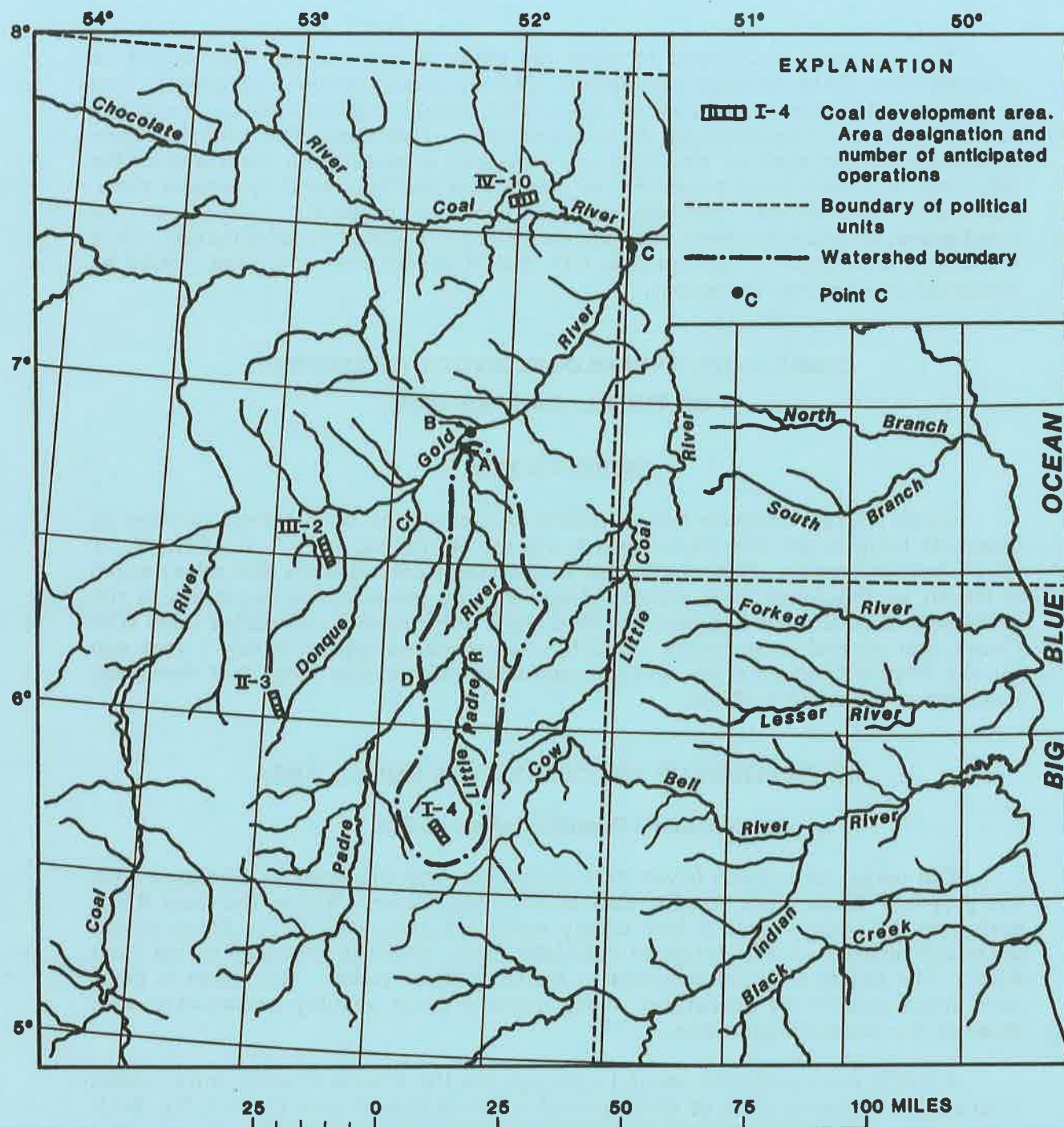


Figure B-1.--Map of the Coal River basin, showing maximum extent of cumulative impact area for the proposed Black Hole mine.

increased salt load delivered to the Coal River below Point C and contributed by the mines in the Gold River basin, is not great enough to be considered as an accumulated impact. Calculations support the same conclusion at Point B. (See CHIA for Prairie Chicken mine.) The additional salt load contributed by the proposed mine is not likely to require a different conclusion. Therefore, Point A was considered the maximum possible downstream extent of the surface CIA for this CHIA.

The maximum upstream extent of the surface CIA is marked by the watershed boundaries of East Fork Padre River and the lower Padre River. The upper Padre River basin was excluded because it contains no mines. Any effects of the upper Padre River on the CHIA can be input at the point of truncation (Point D).

Working CIA

All mining operations and leases in Area I, including completed operations, are shown in figure B-2. Operation 4 is the proposed Black Hole mine. Operation 1 was officially completed on November 30, 1979 (date of final bond release), and is no longer considered a mining operation. Operations 2 (Mud Hen mine) and 5 (Prairie Chicken mine) are active mines. Operation 6 is a leased tract for which an approved RRPP is available. Operations 3, 7, 8, and 9 are leases for which RRPP's have not been submitted. By definition, operations 2, 4, 5, and 6 must be considered as "anticipated" mining operations for CHIA purposes.

Pussy Cat Creek is the farthest downstream tributary whose precipitation and snowmelt discharge events are likely to be affected by these operations. Therefore, Point X was considered as the downstream limit of the CIA for surface-water analysis. The watershed above Point X was delineated as shown in figure B-2, and this area was considered to be the surface CIA. Although operations 1, 3, 7, and 8 lie within this CIA, they are not required to be included as "anticipated" mining. The regulatory authority has received no indication that permit applications will be submitted for any of these operations in the near future. Therefore, they were not included as anticipated operations for this CHIA. The areas that these operations occupy were included in the analysis as integral parts of the hydrologic system, but it was assumed that they would not be disturbed by mining and, therefore, would not directly affect the magnitudes of impacts for this particular CHIA.

The geologic strata that could be affected by the anticipated mining are the overburden, Quaternary sediments (valley alluvium), the coal seam, the shale formation under the coal, and a sandstone formation beneath the shale. The regional dip of these strata is 1° to 2° W. The coal outcrops along a line generally trending northwest to southeast.

The overburden is a member of the Wachou Formation and consists of interbedded siltstone and claystone. These materials are generally uniformly textured and moderately to well cemented. Most of the permeability of these materials is due to fracturing. The fractures contain small amounts of water that is sometimes used for domestic livestock. Overburden water is recharged by infiltration in upland areas. It generally moves through the overburden from south to north and discharges into the underlying coal seam and into the alluvium along the stream valleys.

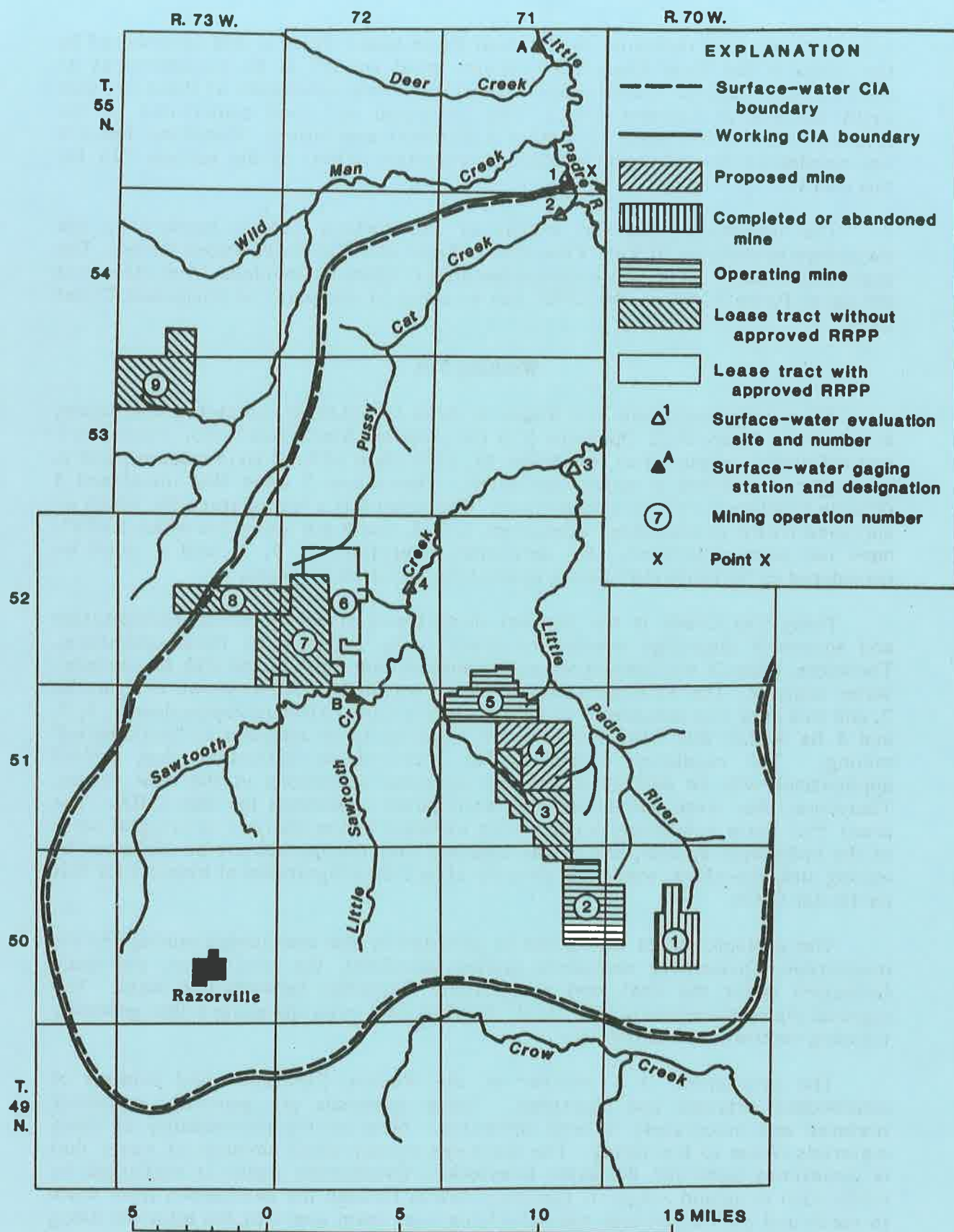


Figure B-2.--Anticipated mining operations associated with the proposed Black Hole mine, and surface-water CIA and ground-water CIA.

Quaternary sediment deposits are found along the larger stream valleys in the area. These deposits consist of both streamlaid and colluvial materials and serve as the main discharge area for the coal aquifer. Here, the water is either consumed by evapotranspiration or discharged to the surface farther downstream in the system.

The coal seam averages 80 feet in thickness and contains significant quantities of water. The coal is saturated through its entire thickness and is under artesian pressure. The coal's permeability is due to fracture systems and varies greatly over the area. Yields of wells in the coal vary from 1 to 10 gallons per minute. The coal is recharged along its outcrop and by some leakage through the overburden. It discharges into the Quaternary deposits along the stream valleys.

Immediately beneath the coal is a consistent layer of dense claystone that varies from 2 to 10 feet in thickness. This material (the underclay layer) is an effective barrier to water movement between the coal and the underlying rocks. Other sub-coal rocks are 500 to 700 feet thick and consist mainly of well-cemented shales. There apparently are only a few fracture zones in these rocks. Although these rocks contain some water, yields to wells are generally too small to be useful. For this analysis, these rocks and the underclay layer were considered to be significant aquacludes. The overburden, the coal, and the valley alluvium aquifers are referred to as the near-surface ground-water system. All strata below the coal were considered to be part of the deep ground-water system.

Ample volumes of potable water are available from the Deep Sands aquifer directly beneath the shales. This aquifer is composed of poorly cemented medium sand and is 700-800 feet thick. It crops out 50-60 miles east of the permit area along the eastern edge of the structural basin. The outcrop is the aquifer's main recharge area. The aquifer is confined; its potentiometric surface is approximately at the level of the land surface, and it slopes to the north-northwest at about 0.00009 foot per foot. There are no points within 100 miles of the permit area where this aquifer is known to discharge directly to the surface. However, some upward leakage to the alluvium along the Padre River is probable.

The short-term impacts of the mining on the near-surface ground-water system of this area are dewatering of the coal and overburden in and adjacent to the mine pits. Longer term impacts include the increased mineralization of water in the resaturated spoils and migration of this water off the permit areas and through the system. For the purpose of delineating the working CIA, estimated extent of life-of-mine drawdowns as submitted in the permit applications of operation 2, 4, and 5 were used. For operation 6, the drawdowns in the coal and overburden aquifers were assumed to extend from the permit boundary the same distances as those for operation 2. These drawdown zones are shown in figure B-3 and represent estimated drawdowns of more than 5 feet.

Likewise, paths that the mineralized water will follow in moving from the resaturated spoils to probable discharge points were adopted from the respective permit applications. However, because the aquifer discharge points are so near the permit areas, the pollution paths are all within the coal aquifer drawdown zones and, therefore, were not delineated in figure B-3. The delineation of the ground-water CIA for the overburden and coal aquifers (near-surface system) is shown in figure B-3. A composite of the cumulative impact area for the surface water system and that for the near-surface ground-water system constitutes the working

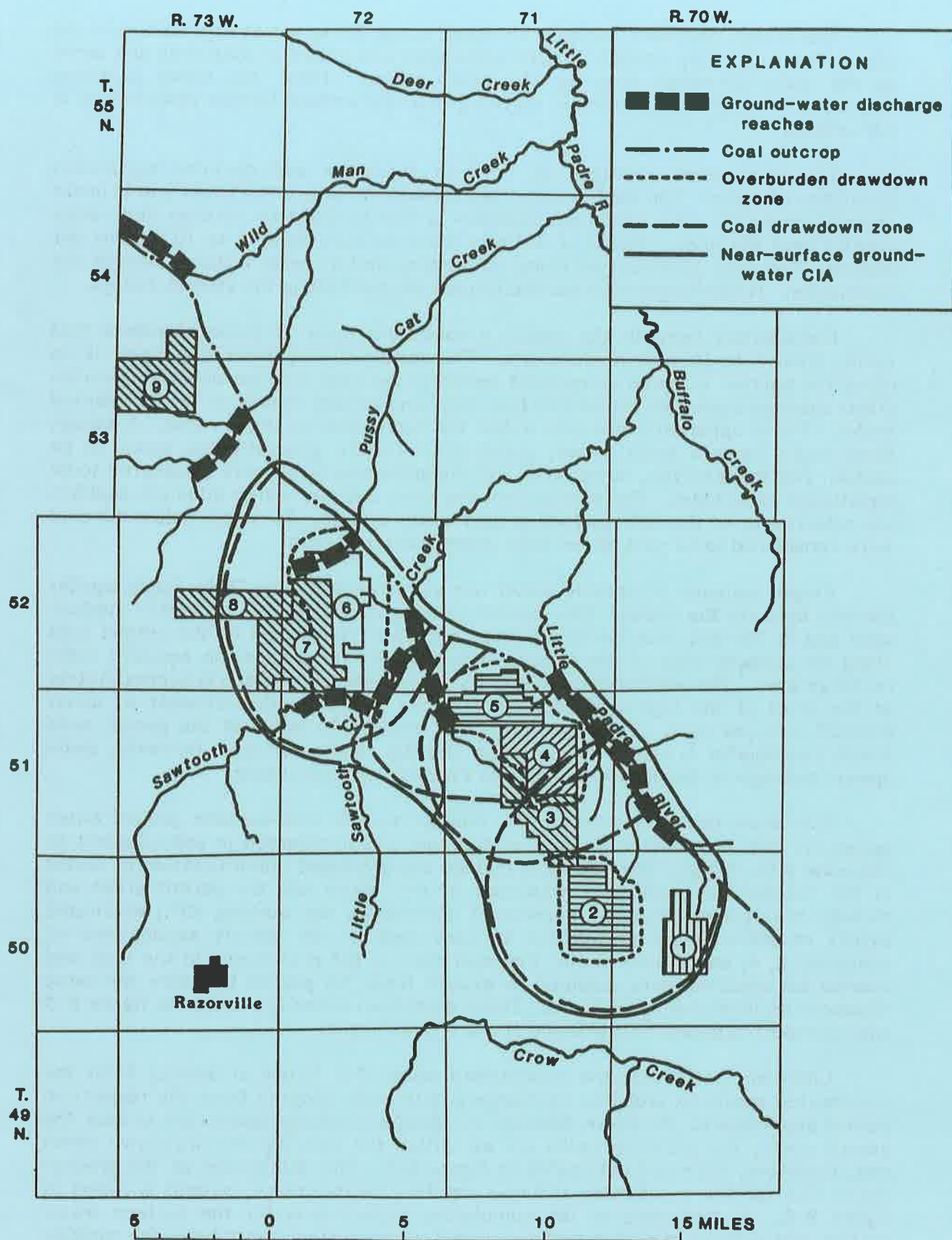


Figure B-3.--Estimated drawdown zones in near-surface aquifers, and near-surface ground-water CIA.

CIA. The working CIA was delineated by overlaying figures B-2 and B-3 and is shown in figure B-2.

The area of cumulative impacts in the Deep Sands aquifer was delineated and analyzed separately from the above impact area because this aquifer is, to a large degree, isolated from the near-surface hydrologic system by intervening aquacludes. Operations 2, 4, and 5 obtain some water by pumping from this aquifer. However, the permit applications for these operations do not show the extent of anticipated drawdown zones resulting from such pumping. Only the drawdowns expected at the wells are given.

For the purpose of delineating the cumulative impact area of these wells, drawdown zones were estimated with the Theis nonequilibrium formula for a confined aquifer. Transmissivity and storage coefficient values of 2,000 gallons per day per foot and 0.0002, respectively, were used. These values are the maximum values found in the individual permit applications. The wells were assumed to be pumped one-half the time over a 30-year period at a rate of 250 gallons per minute. The resulting composite drawdown zone is shown in figure B-4. This delineation represents drawdowns greater than 20 feet. The travel paths of contaminants through the Deep Sands aquifer are not represented in this delineation because the possibility that the mining operations would degrade this water is highly remote. The introduction of contaminants through the wells penetrating the aquifer is the only way such degradation could occur. If this should occur, immediate heavy pumping at the culprit well should remove the offending contaminant before it could significantly spread through the aquifer.

BASELINE HYDROLOGIC CONDITIONS

Baseline hydrologic information is needed to define the hydrologic system as it exists prior to mining of the proposed operation. This definition provides a base from which to project the probable impacts of the "anticipated mining," including the proposed operation, upon the CIA.

The streams draining the CIA are shown in figure B-2. Two long-term streamflow records are available in this area. Nineteen years of continuous water and sediment discharge records have been collected on the Little Padre River at Station A (fig. B-2). In addition, water temperature, pH, electrical conductivity, total dissolved solids, sulfate ion, total iron and total manganese concentrations have been measured on a monthly basis for the past 5 years. Also, one water sample per year has been analyzed for 17 additional chemical constituents. This record provides good definition of the 2-, 10-, and 25-year peak discharge, low flow characteristics, and the water quality at that site.

Eight years of continuous water discharge records have been collected on Sawtooth Creek at Station B (fig B-2). The same water-quality parameters that have been measured at Station A have been measured at Station B for 2 years. The records at these two sites form the basis for estimation of premining flow characteristics at evaluation sites 1-4.

The streamflow record at Station B was extended in time using the methods suggested by Searcy (1960), and the long-term record at Station A. In addition, a series of discharge measurements have been made at the four evaluation sites over

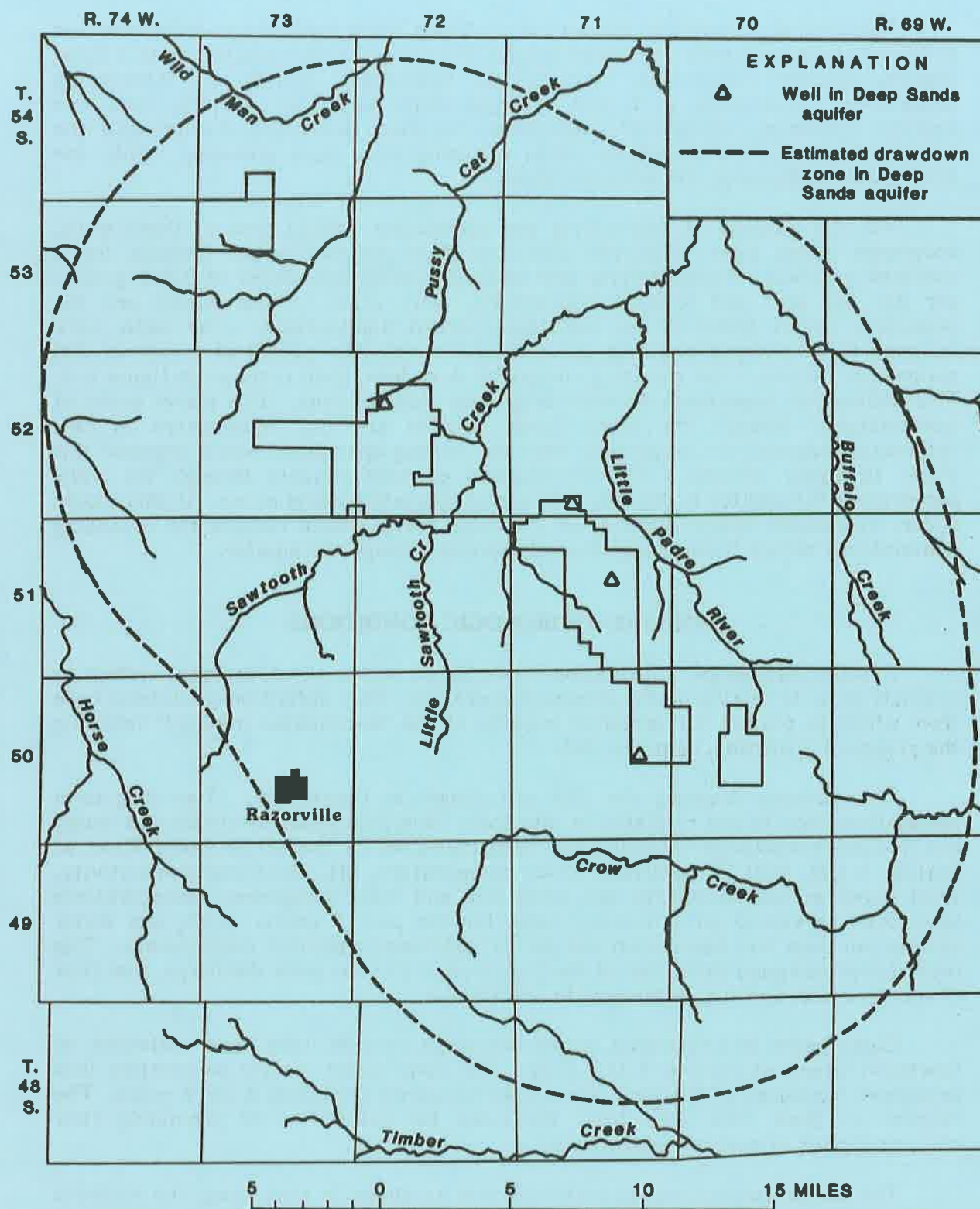


Figure B-4.--Cumulative impact area of Deep Sands aquifer.

the past 2 years. A regression equation for each evaluation site was developed with these measurements. The measurements at sites 1 and 2 were related to coincident discharges at Station A, whereas the measurements at sites 3 and 4 were related to the extended record at Station B. Using the regression equations, the flow characteristics at the four evaluation sites were estimated. The flow characteristics of these same evaluation sites were first estimated for the Prairie Chicken mine. The values were then established as base values from which to calculate material damage thresholds to be used in all subsequent CHIA's that include these evaluation sites. The base mean monthly discharges (Qmm) and average monthly 7-day low-flow discharges (7Qam) are listed in table B-1.

Table B-1.--Base discharge rates established by regulatory authority for CHIA evaluation sites*

(All values are in cubic feet per second. Qmm = Mean monthly discharge;
7Qam = Average monthly 7-day low-flow discharge)

Month	Evaluation site							
	1		2		3		4	
	<u>Qmm</u>	<u>7Qam</u>	<u>Qmm</u>	<u>7Qam</u>	<u>Qmm</u>	<u>7Qam</u>	<u>Qmm</u>	<u>7Qam</u>
Jan.	2.21	0.35	0.55	0.04	0.66	0.12	1.00	0.14
Feb.	3.70	0.40	0.93	0.40	1.11	0.14	1.66	0.22
Mar.	4.53	2.00	1.13	0.20	1.36	0.72	2.04	1.08
Apr.	6.91	1.80	1.73	0.18	2.07	0.65	3.11	0.97
May	4.03	2.20	1.01	0.22	1.21	0.79	1.81	1.19
June	73.1	2.70	18.3	0.68	21.9	0.81	32.9	1.21
July	26.3	2.00	6.58	0.50	7.89	0.60	11.0	0.90
Aug.	7.14	2.10	1.79	0.52	2.14	0.63	3.21	0.95
Sept.	0.58	0.22	0.15	0.02	0.17	0.08	0.26	0.12
Oct.	0.03	0.00	0.01	0.00	0.01	0.00	0.01	0.00
Nov.	0.07	0.04	0.02	0.00	0.02	0.01	0.03	0.03
Dec.	0.30	0.11	0.10	0.00	0.08	0.04	0.12	0.07

*Baseline discharges for Prairie Chicken mine were basis for these values. Base discharges will be used for all subsequent CHIA's that include these evaluation sites.

MATERIAL DAMAGE CRITERIA

The criteria for determining material damage potential of surface coal mining has been previously established and justified by the regulatory authority and was used to make such a determination for the Prairie Chicken mine CHIA. The same criteria apply to the Black Hole mine and are restated here.

Except for the area occupied by the city of Razorville, all land within the CIA is used for agricultural purposes, mainly livestock grazing, and this is the most likely postmining land use in the foreseeable future. Therefore, the regulatory authority has determined that the land and waters of the CIA should be restored and maintained to support this use, in particular livestock grazing, and the material damage criteria applied are based on that premise.

The applicable material damage thresholds for all surface hydrology evaluation sites shown in figure B-2 are listed below.

<u>Site</u>	<u>Parameter</u>	<u>Material damage threshold</u>
All	Average monthly 7-day low-flow rate (<u>7Q_{am}</u>).	50% of <u>7Q_{am}</u> base rate, Mar. 1-Aug. 31.
All	Mean monthly discharge rate (<u>Q_{mm}</u>).	$\pm 50\%$ of <u>Q_{mm}</u> base rate, Mar. 1-Aug. 31.
All	Total dissolved solids.	5,000 mg/L.
All	pH	4.5-9.0.
All	Sulfate ion	3,000 mg/L.
1	Manganese	1.0 mg/L.
2,3,4	Manganese	2.0 mg/L - Average of daily values for 30 consecutive days.
All	Total iron (Fe)	6.0 mg/L.

For the months of September through April, streamflows within the CIA are too small for any useful purpose and the regulatory authority has determined that material damage to streamflow quantity cannot occur during that period of the year.

IDENTIFICATION OF HYDROLOGIC CONCERNS

The objective of this CHIA is to determine the probable cumulative hydrologic impacts of the anticipated mine operations within the CIA delineated in the preceding section of this report. Impacts on the quality and quantity of the surface and ground water, with particular emphasis on the availability of water, are addressed as required by SMCRA. The following discussion identifies the critical hydrologic system segments that were analyzed, the specific parameters analyzed, and the points in the systems at which the parameters were evaluated.

The climate of the area is semiarid. Mean annual precipitation is about 16.0 inches. About one-third of this occurs during the months of May and June. Potential evaporation exceeds 50 inches per year and about 15 inches of the annual precipitation is lost to evapotranspiration. Of the remaining inch, about 0.3 inch runs off the surface, and the rest infiltrates.

The topography of the CIA consists of gently rolling hills of low relief. Topographic features were formed by streams eroding into the nearly flat lying Watchou Formation. The stream channels form dendritic drainage patterns. Upper reaches of most stream channels carry only ephemeral flows. Lower reaches that are eroded into or through the coal may carry intermittent or very small perennial flows derived from the coal aquifer. Between storm- or snowmelt-produced runoff events, this water normally stands or very slowly flows through a series of large pools. Maximum relief between valley floors and adjacent ridges is about 150 feet. Total relief of the CIA is about 500 feet. Premining hillslope gradients range from zero to 40 percent and average 6.5 percent. Eighty percent of the slope gradients are less than 10 percent.

The primary use of water in this area is for livestock and wildlife. Water for this purpose is obtained from wells in the overburden or coal, and by retention of surface runoff in small reservoirs. There have been some attempts at irrigation, but, in general, there is insufficient supply of water from the near-surface system, and it is too poor in quality for successful irrigation. The three available mine plans all indicate grazing as the postmining land use, and it is reasonable to assume that the postmining land use for operation 6 will also be grazing. There has been limited domestic use of ground water from the overburden and coal aquifers, although State and U.S. Public Health standards indicate the water to be unsuitable for human consumption. The best water for human consumption is obtained from the Deep Sands aquifer, which lies 800-1,000 feet below the land surface. The two presently operating mines each have a well tapping this aquifer. The city of Razorville obtains most of its water supply from five wells tapping the Deep Sands aquifer. The wells are located about 25 miles due west of the proposed Black Hole mine.

The concentrations of total dissolved solids in the few samples of surface runoff obtained to date range from 1,060 to 3,200 mg/L. Major constituents are manganese, sodium, calcium, and sulfate. The pH ranged from 7.0 to 9.2. The concentrations of total dissolved solids in ground-water samples range as follows: Overburden, 1,100 to 3,600 mg/L (calcium magnesium sulfate); coal, 800 to 3,800 mg/L (sodium sulfate bicarbonate); Deep Sands, 275 to 1,500 mg/L (sodium calcium bicarbonate sulfate). Concentrations of iron, sulfates, and nitrates in these aquifers frequently exceed drinking water standards.

A direct effect of the anticipated mining is to remove and replace the coal aquifer with fragmented and dewatered overburden material in a broken strip across the CIA. This will cause a redirection toward the reclaimed spoils of the water flow patterns in the coal and overburden adjacent to the reclaimed pits. Until these spoils are resaturated, they constitute a major discontinuity or barrier to the movement of this water toward its present discharge points in the stream valley alluvium.

A subsequent direct effect is that water moving into the reclaimed spoils will become more highly mineralized because of the increased surface area of the fragmented material. Once these spoils are resaturated and flow patterns revert to premining patterns, this highly mineralized water will move into and through the downgradient coal and overburden to the stream valley alluvium and, eventually, into the surface streamflow.

It is obvious from the above physical descriptions of the CIA, of the occurrence of water therein, and of the direct effects of the mining on the hydrology that the major concern relative to the cumulative effects of mining on the hydrology of this area is for the maintenance of already limited amounts of water in the near-surface system available for present uses (i.e., livestock and wildlife watering). This means that the quantity, quality, and distribution of water presently obtained from surface runoff and from the coal and overburden aquifers must be maintained or be made available at present levels. Drawdowns in the coal and overburden aquifers may affect perennial and intermittent streamflows. These drawdowns may also affect some of the wells that now provide water for livestock. An additional concern is that the withdrawal of water from the Deep Sands aquifer for mining-related uses not affect the water supply to the Razorville wells or the cost of pumping that water.

In order to address these concerns, the specific objectives of this CHIA are (1) to determine the change in quantities of water reaching the off-permit stream system, (2) to determine the change in the quality of water that resaturates the reclaimed spoils and eventually reaches the surface-water system and to evaluate the time needed for the spoils to resaturate and for the water to subsequently reach the stream system, (3) to evaluate any change in sediment load to the stream system during and after mining and reclamation, and (4) to determine the effect of the mine wells on the city of Razorville's wells.

The specific parameters used to evaluate each of the stated objectives were as follows:

- Surface-water flow parameters: Mean monthly discharge rate (Q_{mm}) and average monthly 7-day low-flow rate ($7Q_{am}$).
- Ground-water flow parameter: Drawdown of potentiometric surfaces due to pit seepage.
- Water-quality parameters: Total dissolved solids concentration, sulfate ion concentration, total manganese concentration, total iron (Fe) concentrations, and monthly sediment load.

Surface-water parameters were evaluated at the sites shown in figure B-2. All parameters were evaluated at each site except that low-flow rates were only evaluated at sites with intermittent or perennial flows. Ground-water discharge rates to valley alluvium were evaluated as changes in streamflow rates along the ground-water discharge reaches shown in figure B-3. Water quality parameters were evaluated at all flow evaluation sites and within the projected ground-water drawdown zones.

(READER NOTE: For the sake of brevity, the remainder of this CHIA example will address only the water quantity impacts to the surface hydrology system. However, an actual CHIA **must** address all concerns identified in Element B.)

ANALYSIS OF HYDROLOGIC IMPACTS

The combinational approach was selected for this analysis. The same approach was used for the Prairie Chicken mine CHIA and that assessment showed by wide margins that there was little possibility that the analyzed parameters would exceed material damage thresholds. The only real difference in conditions

for the two assessments is that an additional year of data is now available and a PHC analysis for the Black Hole lease area is available, whereas many estimates were applied to that area in the previous CHIA. The additional data tends to confirm the parameter values estimated for operation 6, and those same values will also be used for this CHIA.

Projected maximum changes in Q_{mm} and 7Q_{am} discharges were obtained from the hydrologic analyses (PHC's) of the individual maine plan applications. These values are listed in tables B-2 and B-3, respectively. Next, these discharge changes were routed to the four impact evaluation sites. This was done by simple summation at each evaluation site of all nonsummed discharge change values, or of evaluation site sums immediately upstream from the summing site. Thus, the values for site 3 are the sums of discharge change quantities from mine operations 2, 4, and 5 (2-LP, 4-LP, 5-LP, tables B-2, B-3). This routing procedure was considered adequate in this case because discharge changes were routed rather than the total stream discharge, and, therefore, it was not necessary to account for incremental discharge changes (due to nonmining increases or depletions) from within the intervening stream reach. Also, this routing procedure does not account for discharge changes caused by changes in stream channel geometry (width, depth, gradient, roughness) within the stream reach. However, the procedure should give conservative discharge estimates.

Table B-2.--Mean monthly discharge: Projected maximum changes for each mine operation

(All values are in cubic feet per second. 2-LP = Operation number and stream designation: LP, Little Padre River; ST, Sawtooth Creek; PC, Pussy Cat Creek. See figure B-2 for locations of mine operations)

Month	Operation and receiving stream						
	2-LP	4-LP	5-LP	4-ST	5-ST	6-ST	6-PC
January	-0.06	-0.05	-0.04	-0.13	-0.10	-0.09	-0.05
February	-0.10	-0.09	+0.07	-0.22	+0.17	+0.15	+0.08
March	-0.12	-0.11	+0.08	-0.27	-0.20	-0.18	-0.10
April	-0.19	-0.17	-0.12	+0.40	-0.31	-0.28	-0.09
May	+0.11	-0.10	-0.07	-0.24	-0.18	-0.16	-0.16
June	-1.91	-1.81	-1.25	-4.28	-3.29	-2.96	-0.09
July	-0.70	-0.65	+0.47	-1.53	-1.18	-1.06	-1.65
August	-0.19	-0.16	+0.13	-0.42	-0.32	-0.29	-0.59
September	-0.04	-0.03	-0.03	-0.03	-0.01	-0.01	-0.16
October	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
November	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	+0.01
December	-0.02	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01

Table B-3.--Average monthly 7-day low flows: Projected maximum changes for each mine operation

(All values are in cubic feet per second. 2-LP = Operation number and stream designation: LP, Little Padre River; ST, Sawtooth Creek; PC, Pussy Cat Creek. See figure B-2 for locations of mine operations)

Month	Operation and receiving stream						
	2-LP	4-LP	5-LP	4-ST	5-ST	6-ST	6-PC
January	-0.01	-0.01	-0.01	-0.02	+0.02	-0.02	-0.04
February	-0.01	-0.01	+0.01	-0.03	-0.03	-0.03	-0.04
March	-0.07	-0.06	-0.05	-0.14	-0.11	-0.09	-0.02
April	-0.06	-0.05	-0.04	-0.13	-0.10	-0.09	-0.02
May	-0.08	-0.06	-0.05	-0.18	-0.12	-0.10	-0.02
June	-0.08	-0.06	-0.05	-0.16	-0.12	-0.11	-0.06
July	-0.06	-0.05	-0.04	-0.12	+0.09	-0.08	-0.05
August	-0.06	-0.05	+0.04	-0.12	-0.09	-0.08	-0.05
September	-0.01	-0.01	00.00	-0.01	+0.01	-0.01	-0.01
October	00.00	00.00	00.00	00.00	00.00	00.00	00.00
November	00.00	00.00	00.00	00.00	00.00	00.00	00.00
December	00.00	00.00	00.00	-0.01	-0.01	00.00	00.00

The routed Q_{mm} and 7Q_{am} discharge changes are listed in tables B-4 and B-5, respectively. These are the maximum discharge changes expected at the evaluation as a result of the anticipated mining.

POTENTIAL FOR MATERIAL DAMAGE

The material damage threshold values for surface discharge parameters are calculated from base discharges set by the regulatory authority. The base discharge values are the Q_{mm} and 7Q_{am} discharges determined for each evaluation site at the time that the Prairie Chicken CHIA was prepared.

The material damage criteria set damage thresholds at 50 percent of the base discharge values. Thus, the total allowable discharge change (Q_a) from base values is +50 percent of the base discharge. The base discharge values are listed in table B-1. The Q_a values (allowable discharge changes before material damage occurs) are listed in tables B-4 and B-5. The projected changes (Q_c) due to anticipated mining are also shown in tables B-4 and B-5. Comparison of the corresponding Q_a and Q_c values indicates the potential for material damage. In this case, the comparison shows that 40-60 percent of the allowable change values remain, thus indicating no potential damage to surface water quantities due to the anticipated mining.

The above-listed Qc values are conservative in that it was initially assumed that the maximum impacts of all the mines would occur at the same time. In reality, the maximum impacts of Operations 2 and 6 will probably occur some years apart, meaning that larger percentages of the allowable changes remain than is indicated by this analysis.

On the basis of the preceding cumulative hydrologic impact analysis, the regulatory authority has determined that the cumulative impacts of the Black Hole mine will not cause material damage to the hydrologic balance that affects surface-water quantities.

Table B-4.--Mean monthly discharges: Estimated maximum changes and allowable changes at evaluation sites

(All values are in cubic feet per second. Qa = Allowable discharge changes before material damage occurs. Qc = Estimated maximum discharge changes. Qc values for Site 1 are sum of values for Sites 2, 3, and 4. Qc values for Site 2 are sum of values 6-PC from table B-2. Qc values for Site 3 are sum of values 2-LP, 4-LP, 5-LP from table B-2. Qc values for Site 4 are sum of values 4-ST, 5-ST, 6-ST from table B-2. NA - Not applicable)

Month	Evaluation site							
	1		2		3		4	
	<u>Qc</u>	<u>Qa</u>	<u>Qc</u>	<u>Qa</u>	<u>Qc</u>	<u>Qa</u>	<u>Qc</u>	<u>Qa</u>
Jan.	-0.52	NA	-0.05	NA	-0.15	NA	-0.32	NA
Feb.	+0.06	NA	+0.08	NA	-0.12	NA	+0.10	NA
Mar.	-0.90	±2.26	-0.10	±0.56	-0.15	±0.68	-0.65	±1.02
Apr.	-0.76	±3.45	-0.09	±0.86	-0.48	±1.04	-0.19	±1.56
May	-0.80	±2.01	-0.16	±0.50	-0.06	±0.60	-0.58	±0.90
June	-15.6	±36.5	-0.09	±9.10	-4.97	±11.0	-10.5	±16.4
July	-6.30	±13.2	-1.65	±3.29	-0.88	±3.97	-3.77	±5.90
Aug.	-1.84	±3.57	-0.59	±0.90	-0.22	±1.07	-1.03	±1.60
Sept.	-0.31	NA	-0.16	NA	-0.10	NA	-0.05	NA
Oct.	-0.07	NA	-0.01	NA	-0.01	NA	-0.03	NA
Nov.	-0.05	NA	+0.01	NA	-0.03	NA	-0.03	NA
Dec.	-0.09	NA	-0.01	NA	-0.04	NA	-0.04	NA

Table B-5.--Average monthly 7-day low flows: Estimated maximum changes and allowable changes at evaluation sites

(All values are in cubic feet per second. Qa = Allowable discharge changes before material damage occurs. Qc = Estimated maximum discharge changes. Qc values for Site 1 are sum of values for Sites 2, 3, and 4. Qc values for Site 2 are sum of values 6-PC from table B-2. Qc values for Site 3 are sum of values 2-LP, 4-LP, 5-LP from table B-2. Qc values for Site 4 are sum of values 4-ST, 5-ST, 6-ST from table B-2. NA - Not applicable)

Month	Evaluation site							
	1		2		3		4	
	<u>Qc</u>	<u>Qa</u>	<u>Qc</u>	<u>Qa</u>	<u>Qc</u>	<u>Qa</u>	<u>Qc</u>	<u>Qa</u>
Jan.	-0.07	NA	-0.04	NA	-0.01	NA	-0.02	NA
Feb.	-0.14	NA	-0.04	NA	-0.01	NA	-0.09	NA
Mar.	-0.54	-1.00	-0.02	-0.10	-0.18	-0.36	-0.34	-0.54
Apr.	-0.49	-0.90	-0.02	-0.09	-0.15	-0.34	-0.32	-0.48
May	-0.61	-1.10	-0.02	-0.11	-0.19	-0.40	-0.40	-0.90
June	-0.84	-1.35	-0.06	-0.34	-0.19	-0.40	-0.39	-0.60
July	-0.49	-1.00	-0.05	-0.25	-0.15	-0.30	-0.29	-0.45
Aug.	-0.49	-1.05	-0.05	-0.26	-0.15	-0.31	-0.29	-0.48
Sept.	-0.06	NA	-0.01	NA	-0.02	NA	-0.03	NA
Oct.	00.00	NA	00.00	NA	00.00	NA	00.00	NA
Nov.	00.00	NA	00.00	NA	00.00	NA	00.00	NA
Dec.	-0.02	NA	00.00	NA	00.00	NA	-0.02	NA

REFERENCE

Searcy, J. K., 1960, Graphical correlation of gaging-station records: U.S. Geological Survey Water-Supply Paper 1541-C, 23 p.